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A NEW THEORY OF THE SUSPENSION SYSTEM WITH STIFFENING TRUSS.

By A. JAY DUBOIS, PH.D.

Professor of Dynamic Engineering in the Sheffield Scientific School of Yale College.

(Concluded from page 173.)

ORDINARY METHOD INCORRECT.

The usual method adopted for the discussion of the stiffening girder is to assume that the truss distributes any partial load over the cable, *so as to cause it to take effect as a uniform load.* The new curve of the cable is thus assumed to be still a parabola, with its vertex at the centre, whatever may be the loading. By finding, then, the deflections at centre of cable and truss, and equaling them, that portion of the partial load which acts on the cable as a uniformly distributed load is easily found. This is the same as the upward load on the truss. The moment at any point of the truss can then be determined.

This method is, however, essentially incorrect. The truss, it is true, does act to distribute any partial load over the cable, but we have no right to assume this distributed load is uniform. In point of fact it is not uniform. The new curve of the cable is not a parabola

whose vertex is at the centre, but it is a curve similar to that shown in Fig. 8. The distributed load on the cable is therefore *not* uniform, but follows some other law of distribution.

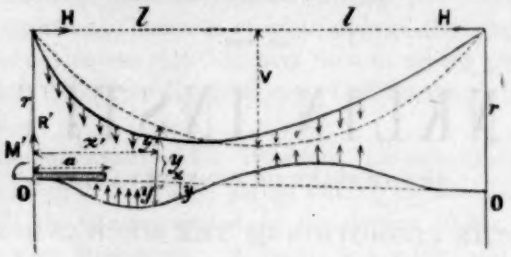

Fig. 8.

This distributed load, whatever its law may be, acts through the suspenders as an equal upward load upon the truss. The elastic curve of the truss is then similar to that shown in Fig. 8. If we neglect the slight increase of length of the suspenders, we can assume that *the deflections of truss and cable at any point are equal.*

Notation.

Let the moving load per unit of length be m, and let this load extend over a distance, a, from the left end. Let R_1 be the reaction at the left end, *positive* when it acts upwards, and M_1 be the moment at the left end. Any moment tending to cause compression in the upper flange is *positive*. Take O, Fig. 8, as the origin of co-ordinates. For any point distant x_1 from the left end, let y' be the ordinate to the *original* curve of ccable. x_1 is positive towards the right, and y' is positive when laid off above OO'. Let the deflection of the truss at the same point x_1 be y''. y'' is also positive when laid off *above* OO'. Let Y be the ordinate at the same point x_1 of the *new* curve of cable. Then at any point x_1 we have generally

$$Y = y' + y'' \qquad (27)$$

Let x be any point of the truss on the right of x_1 and y be the corresponding deflection. Let v, as always, be the versine of original curve of cable, and r the height of tower, and l the half span.

Moment of Distributed Cable Load.

Since the curve of the cable is originally a parabola, under the action of the entire dead load, which may be considered as uniform,

its equation is easily found from (10), by transferring the origin from the centre to O,

$$y' = r - \frac{2\,v\,x_1}{l} + \frac{v\,x_1^2}{l^2}$$

We have then from (27)

$$Y = r - \frac{2\,v\,x_1}{l} + \frac{v\,x_1^2}{l^2} + y''$$

for the ordinate to new curve of cable at any point x_1, y'' being negative when below horizontal.

The tangent of the angle of inclination with horizontal of the new curve of cable at any point x_1 is then

$$\frac{d\,Y}{d\,x_1} = -\frac{2\,v}{l} + \frac{2\,v\,x_1}{l^2} + \frac{d\,y''}{d\,x_1} \qquad (28)$$

The new curve is an equilibrium curve. Its horizontal force at all points is therefore constant. Let this constant horizontal force, or pull of cable, be H.

Then $H\,\frac{d\,Y}{d\,x_1}$ is the vertical force at any point. The differential of this will give the elementary load on cable at any point x_1,

$$H\,\frac{d^2\,Y}{d\,x_1^2}\,d\,x_1 = H\,\frac{2\,v}{l^2}\,d\,x_1 + H\,\frac{d^2\,y''}{d\,x_1^2}\,d\,x_1 \qquad (29)$$

The moment of this elementary load with reference to any point x on the right of x_1, is $H\,\frac{d^2\,Y}{d\,x_1^2}\,d\,x_1\,(x - x_1)$

Therefore $x_1 = x$

$$\int_{x_1=0} H\,\frac{d^2\,Y}{d\,x_1^2}\,d\,x_1\,(x - x_1) = \text{moment of entire distributed}$$

load on cable between left end and any point x_1 with reference to x.

We have then from (29)

$$\int_{x_1=0}^{x_1=x} H\,\frac{d^2\,Y}{d\,x_1^2}\,d\,x_1\,(x - x_1) = \int_{x_1=0}^{x_1=x} H\,x\,\frac{d^2\,Y}{d\,x_1^2}\,d\,x_1 - \int_{x_1=0}^{x_1=x} H\,\frac{d^2\,Y}{d\,x_1^2}\,x_1\,d\,x_1$$

$$= H\int_{x_1=0}^{x_1=x}\frac{2\,v\,x}{l^2}\,d\,x_1 + H\int_{x_1=0}^{x_1=x} x\,\frac{d^2\,y''}{d\,x_1^2}\,d\,x_1 - H\int_{x_1=0}^{x_1=x}\frac{2\,v}{l^2}\,x_1\,dx_1 - H\int_{x_1=0}^{x_1=x}\frac{d^2\,y''}{d\,x_1^2}\,x_1\,dx_1$$

Performing the integrations, we have, since when $x_1 = 0$, $\frac{d^2y''_0}{d\,x_1^2} = 0$, if the truss is fixed horizontally at the ends,

$$\int_{x_1=0}^{x_1=x} H\,\frac{d^2Y}{dx_1^2}\,dx_1(x-x_1) = H\,\frac{2\,v\,x^3}{l^2} + Hx\,\frac{dy}{dx} - H\,\frac{vx^2}{l^2} - H\int_{x_1=0}^{x_1=x}\frac{d^2\,y''}{d\,x_1^2}\,x_1 dx_1$$

$$= H\,\frac{v\,x^2}{l^2} + H\,x\,\frac{dy}{dx} - H\int_{x_1=0}^{x_1=x}\frac{d^2\,y''}{d\,x_1^2}\,x_1\,dx_1 \qquad (30)$$

Let us now consider the final integral in equation (30).

We have from the differential calculus

$$d\,(x\,y) = x\,dy + y\,dx$$

hence

$$x\,dy = d\,(x\,y) - y\,dx$$

Now let $x = x_1$ and $y = \frac{d\,y''}{d\,x_1}$. Then $d\,y = \frac{d^2\,y''}{d\,x_1^2}\,dx_1$ and $x\,dy = \frac{d^2\,y''}{d\,x_1^2}\,x_1\,dx_1$

Hence $\int_{x_1=0}^{x_1=x}\frac{d^2\,y''}{d\,x_1^2}\,x_1\,dx_1 = H\int_{x_1=0}^{x_1=x} d\left[\frac{d\,y''}{d\,x_1}\,x_1\right] - H\int_{x_1=0}^{x_1=x}\frac{d\,y''}{d\,x_1}\,d\,x_1$

Performing the integration and remembering that when $x_1 = 0$, $y'' = 0$ and $\frac{d\,y''}{d\,x_1} = 0$, we have

$$H\int_{x_1=0}^{x_1=x}\frac{d^2\,y''}{d\,x_1^2}\,x_1\,d\,x = H\,x\,\frac{dy}{dx} - H\,y$$

Substituting this in (30) we have

$$\int_{x_1=0}^{x_1=x} H\,\frac{d^2\,Y}{d\,x_1^2}\,d\,x_1\,(x-x_1) = H\,\frac{v\,x^2}{l^2} + H\,y \qquad (31)$$

Equation (31) gives the moment of the entire distributed cable load between the left end and any point distant x from the left end, with reference to that point as a centre of moments.

Elastic Curve of the Truss.

From the theory of flexure we have for the differential equation of the elastic curve the moment at any point from $x = 0$ to $x = a$, or when $x < a$

$$E\,I\,\frac{d^2\,y}{d\,x^2} = R_1\,x - \frac{m\,x^2}{2} + \frac{H\,v\,x^2}{l^2} + H\,y + M_1 \qquad (32a)$$

For any point from $x = 2\,l$ to $x = a$, or when $x > a$

$$E\,I\,\frac{d^2 y_1}{d\,x^2} = R_1(x-2l) - ma(x-2l) + \frac{H\,v}{l^2}(x^2-4l^2) + Hy_1 + M_2 \qquad (32b)$$

where $M_2 = 2\,R_1\,l - m\,a\left(2\,l - \frac{a}{2}\right) + 4\,H\,v + M_1$

where y_1 denotes the deflection at any point beyond the load.

If we differentiate equation (32a) twice, we have

$$E\,I\,\frac{d^3\,y}{d\,x^3} = R_1 - m\,x + \frac{2\,H\,v\,x}{l^2} + H\,\frac{dy}{dx} \qquad (33a)$$

$$E\,I\,\frac{d^4\,y}{d\,x^4} = \frac{2\,H\,v}{l^2} + H\,\frac{d^2\,y}{d\,x^2} - m \qquad (34a)$$

Equation (34a) can be put in simple shape. Thus let

$$\left.\begin{aligned} H\,\tau^2 &= E\,I \\ z &= \frac{2\,v}{l^2} + \frac{d^2\,y}{d\,x^2} - \frac{m}{H} \end{aligned}\right\} \qquad (35a)$$

Then

$$\frac{d\,z}{dx} = \frac{d^3\,y}{d\,x^3}, \quad \frac{d^2\,z}{d\,x^2} = \frac{d^4\,y}{d\,x^4}$$

and equation (34a) becomes

$$\frac{d^2\,z}{d\,x^2} = \frac{z}{\tau^2} \qquad (36a)$$

Integrating* between the limits $x = o$ and x_1 we have

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* The integration is performed as follows:

$$\frac{d^2 z}{dx^2} = \frac{z}{\tau^2}$$

Multiply both sides by $2\,d\,z$, then

$$\frac{2\,d\,z\,d^2\,z}{d\,x^2} = \frac{2\,z\,d\,z}{\tau^2}$$

Integrating $\frac{d\,z^2}{d\,x^2} = \frac{z^2}{\tau^2} + C_1$ (1)

Now in the present case, when $x = o$ $\frac{d\,y}{d\,x} = o$ and from (33a) $\frac{d\,z^2}{dx^2} = \left(\frac{d^2 y}{dx^2}\right)^2 =$

$$z = A\, e^{\frac{x}{\tau}} - B\, e^{-\frac{x}{\tau}} \qquad (37a)$$

where e is the base of the Naperian system of logarithms, or $e = 2{\cdot}7182818$ and A and B are constants of integration to be determined by the special conditions of the case.

In the present case

$\frac{R_1^2}{H^2\,\tau^4}$. Also when $x = o$, $y = o$ and from (32a) $\frac{d^2y}{dx^2} = \frac{M_1}{H\,\tau^2}$. Hence for $x = o$,

$$\frac{z^2}{\tau^2} = \frac{\left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}\right)^2}{\tau^2}$$

Hence
$$C_1 = \frac{R_1^2}{H^2\,\tau^4} - \frac{\left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}\right)^2}{\tau^2} \qquad (2)$$

From (1) we have $d\,x = \dfrac{d\,z}{\sqrt{\frac{z^2}{\tau^2} + C_1}}$

Integrate again and we have

$$x = \tau \log.\left[\frac{z}{\tau} + \sqrt{\frac{z^2}{\tau^2} + C_1}\right] + C_2 \qquad (3)$$

In the present case, for $x = o$ we have

$$C_2 = -\tau \log.\left[\frac{\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}}{\tau} + \frac{R_1}{H\,\tau^2}\right] \qquad (4)$$

From (3) we have

$$e^{\frac{x-C_2}{\tau}} - \frac{z}{\tau} = \sqrt{\frac{z^2}{\tau^2} + C_1} \quad \text{or} \quad z = \frac{\tau}{2}\left(e^{\frac{x-C_2}{\tau}} - C_1\, e^{-\frac{x-C_2}{\tau}}\right)$$

Put $A = \frac{\tau}{2}\, e^{-\frac{C^2}{\tau}}$ and $B = \frac{\tau}{2}\, C_1\, e^{\frac{C^2}{\tau}}$ and we have

$$z = A\, e^{\frac{x}{\tau}} - B\, e^{-\frac{x}{\tau}}$$

which is the equation in the text.

From (4) we have

$$-\frac{C^2}{e^{\tau}} = \frac{R_1}{H\,\tau^2} + \frac{\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}}{\tau}$$

Hence

$$A = \tfrac{1}{2}\left[\frac{R_1}{H\,\tau} + \left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}\right)\right]$$

$$B = \tfrac{1}{2}\left[\frac{R_1}{H\,\tau} - \left(\frac{2\,v}{l^2} - \frac{m}{H} + \frac{M_1}{H\,\tau^2}\right)\right]$$

$$\left.\begin{aligned} A &= \tfrac{1}{2}[K+N] \quad B = \tfrac{1}{2}[K-N] \\ K &= \frac{R_1}{H\tau} \quad N = \frac{2v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2} \end{aligned}\right\} \tag{38a}$$

From (37*a*) we have, after replacing z by its value in (35*a*)

$$\frac{d^2y}{dx^2} = A\,e^{\frac{x}{\tau}} - B\,e^{-\frac{x}{\tau}} - \frac{2v}{l^2} + \frac{m}{H} \tag{39a}$$

Differentiating (39*a*) twice, we have

$$\frac{d^3y}{dx^3} = \frac{A}{\tau}\,e^{\frac{x}{\tau}} + \frac{B}{\tau}\,e^{-\frac{x}{\tau}} \tag{40a}$$

$$\frac{d^4y}{dx^4} = \frac{A}{\tau^2}\,e^{\frac{x}{\tau}} - \frac{B}{\tau^2}\,e^{-\frac{x}{\tau}} \tag{41a}$$

We have also by integration, from (39*a*)

$$\frac{dy}{dx} = \tau A\,e^{\frac{x}{\tau}} + \tau B\,e^{-\frac{x}{\tau}} - \frac{2vx}{l^2} + \frac{mx}{H} + C \tag{42a}$$

when $x = o$, $\frac{dy}{dx} = o$ and hence

$$C = -\tau(A+B) = -\frac{R_1}{H} \tag{43a}$$

Also

$$y = \tau^2 A\,e^{\frac{x}{\tau}} - \tau^2 B\,e^{-\frac{x}{\tau}} - \frac{vx^2}{l^2} + \frac{mx^2}{H} + Cx + D \tag{44a}$$

when $x = o$, $y = o$ and hence

$$D = -\tau^2(A-B) = -\tau^2\left(\frac{2v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}\right) \tag{45a}$$

The values of all the constants are thus given in terms of H_1, M_1 and R_1, which still remain to be found.

For that portion of the elastic curve beyond the load, equation (32*b*) holds good. Differentiate this twice and we have

$$EI\frac{d^3y_1}{dx^3} = R_1 - ma + \frac{2Hvx}{l^2} + H\frac{dy_1}{dx_1} \tag{33b}$$

$$EI\frac{d^4y_1}{dx^4} = \frac{2Hv}{l^2} + H\frac{d^2y_1}{dx^2} \tag{34b}$$

Equation (34*b*) can be put in a simpler shape. Thus, let, as before,

$$\left.\begin{aligned} H\tau^2 &= EI \\ \text{and } z_1 &= \frac{2v}{l^2} + \frac{d^2 y_1}{dx^2} \end{aligned}\right\} \tag{35b}$$

Then equation (34*b*) becomes

$$\frac{d^2 z_1}{dx^2} = \frac{z_1}{\tau^2} \tag{36b}$$

Integrating between the limits $x = 2l$ and x, we have

$$z_1 = \alpha e^{\frac{x-2l}{\tau}} - \beta e^{-\frac{x-2l}{\tau}} \tag{37b}$$

where, as before, e is the base of the Naperian system of logarithms, and α and β are constants of the integration, to be determined by the special conditions of the case.

In the present case

$$\left.\begin{aligned} \alpha &= \frac{\tau}{2}\left(\eta + \phi\right) \quad \beta = \frac{\tau}{2}\left(\eta - \varphi\right) \\ \eta &= \frac{R_1 - m\,a + \frac{4Hv}{l}}{H\tau^2} \\ \varphi &= \frac{2v}{\tau l^2} + \frac{2\,R_1\,l - m\,a\left(2l - \frac{a}{2}\right) + 4\,H\,v + M_1}{H\tau^3} \end{aligned}\right\} \tag{38b}$$

From (37*b*) we have, after replacing z by its value in (35*b*),

$$\frac{d^2 y_1}{dx^2} = \alpha e^{\frac{x-2l}{\tau}} - \beta e^{-\frac{x-2l}{\tau}} \frac{2v}{l^2} \tag{39b}$$

From (39*b*) by differentiating twice, we have

$$\frac{d^3\,y_1}{dx_3} = \frac{\alpha}{\tau} e^{\frac{x-2l}{\tau}} + \frac{\beta}{\tau} e^{-\frac{x-2l}{\tau}} \tag{40b}$$

$$\frac{d^4\,y_1}{dx^4} = \frac{\alpha}{\tau^2} e^{\frac{x-2l}{\tau}} - \frac{\beta}{\tau} e^{-\frac{x-2l}{\tau}} \tag{41b}$$

We have also from (39*b*) by integration between the limits $2l$ and x,

$$\frac{dy_1}{dx} = \tau\,\alpha\, e^{\frac{x-2l}{\tau}} + \tau\,\beta\, e^{-\frac{x-2l}{\tau}} - \frac{2v}{l^2}(x-2l) + \gamma \tag{42b}$$

when $x = 2\,l$, $\frac{d\,y_1}{d\,x} = o$ and

$$\gamma = -\,\tau\,(a+\beta) = -\,\tau^2\,\eta \tag{43b}$$

Integrating again

$$y_1 = \tau^2\,a\,e^{\frac{x-2\,l}{\tau}} - \tau^2\,\beta\,e^{-\frac{x-2\,l}{\tau}} - \frac{v}{l^2}\,(x-2\,l)^2 + \gamma\,(x-2\,l + \delta \tag{44b}$$

when $x = 2\,l$, $y_1 = o$ and

$$\delta = -\,\tau^2\,(a-\beta) = -\,\tau^3\,\varphi \tag{45b}$$

Equation (44*a*) gives the elastic curve of that portion of the truss covered by the load, and (44*b*) of all that portion beyond the load.

All the constants, A, B, C, D and α, β, γ, δ, are given in terms of R_1, M_1 and H. It remains to determine these quantities.

Value of H, R_1 and M_1.

At the point where $x = a$, the two portions of the elastic curve, right and left, have the same deflection and a common tangent. Also the moment and shear at this point are the same for both curves. Hence for $x = a$, equations (44*b*) and (44*a*), (42*b*) and (42*a*), (40*b*) and (40*a*), (41*b*) and (41*a*) are simultaneous.

We have then the following equations of condition:

$$\tau^2\,A\,e^{\frac{a}{\tau}} - \tau^2\,B\,e^{-\frac{a}{\tau}} - \frac{v\,a^2}{l^2} + \frac{m\,a^2}{2\,H} + C\,a + D = \tau^2\,a\,e^{\frac{a-2\,l}{\tau}} - \tau^2\,\beta\,e^{-\frac{a-2\,l}{\tau}} - \frac{v}{l^2}\,(a-2\,l)^2 + \gamma\,(a-2\,l) + \delta \tag{a}$$

$$\tau\,A\,e^{\frac{a}{\tau}} + \tau\,B\,e^{-\frac{a}{\tau}} - \frac{2\,v\,a}{l^2} + \frac{m\,a}{H} + C = \tau\,a\,e^{\frac{a-2\,l}{\tau}} - \tau\,\beta\,e^{-\frac{a-2\,l}{\tau}} - \frac{2\,v}{l^2}\,(a-2\,l) + \gamma \tag{b}$$

$$A\,e^{\frac{a}{\tau}} - B\,e^{-\frac{a}{\tau}} + \frac{m}{H} = a\,e^{\frac{a-2\,l}{\tau}} - \beta\,e^{-\frac{a-2\,l}{\tau}} \tag{c}$$

$$\frac{A}{\tau}\,e^{\frac{a}{\tau}} + \frac{B}{\tau}\,e^{-\frac{a}{\tau}} = \frac{a}{\tau}\,e^{\frac{a-2\,l}{\tau}} + \frac{\beta}{\tau}\,e^{-\frac{a-2\,l}{\tau}} \tag{d}$$

Combining (*c*) and (*d*) by addition and subtraction, we obtain

$$\left.\begin{aligned} 2\,A\,e^{\frac{a}{\tau}} - 2a\,e^{\frac{a-2\,l}{\tau}} &= -\frac{m}{H} \\ 2\,\beta\,e^{-\frac{a-2\,l}{\tau}} - 2\,B\,e^{-\frac{a}{\tau}} &= -\frac{m}{H} \end{aligned}\right\} \qquad \text{(XVI)}$$

Combining (*a*) and (*b*) in the same way, we have after substituting the values of C, D, γ and δ, from (43*a*), (45*a*), (43*b*) and (45*b*), and reducing, precisely the same two equations as (XVI). In like manner the combination of (*b*) and (*c*) gives us precisely the same two equations. So also for the combination of (*a*) and (*d*).

Our four equations of condition give us then in reality only two equations containing R_1, M_1, and H or τ.

It is necessary to find a third equation. This we can easily do, by assuming, in accordance with the ordinary theory, that the curve of the cable remains parabolic even for partial loading. Although this assumption is not theoretically correct, still, in practice, the real curve differs so little from the parabolic, that, *so far as the cable alone is concerned*, the value of H thus found is very exactly the real value of H.

We have then

$$H = \frac{k\,m\,l^2}{2\,v} \qquad \text{(XVII)}$$

where we have already found for k the values:

when $a < l$

$$k = \frac{a^3\,(2\,l - a)}{2\,l^4\left[1 + \frac{9\,E_2\,F_2\,h^2}{4\,E_1\,F_0\,v^2}\right]} \qquad \text{(VIII)}$$

when $a > l$

$$k = \frac{2\,l^4 - a\,(2\,l - a)^3}{2\,l^4\left[1 + \frac{9\,E_2\,F_2\,h^2}{4\,E_1\,F_0\,v^2}\right]} \qquad \text{(VIII}a\text{)}$$

If we put for I_2 its value, viz., $I_2 = F_2\,\frac{h^2}{4}$ we have

$$\tau = \sqrt{\frac{E_2\,F_2\,h^2\,v}{2\,k\,m\,l^2}} \qquad \text{(XVIII)}$$

These values of τ and H, inserted in equations (XVI), will give us two equations containing only R_1 and M_1. We can therefore find

these quantities. Thus, the values of H, τ, R_1 and M_1 can be easily determined for any given value of a.

Temperature Load.

The effect of a rise of temperature of $t°$ above the mean, is to load the truss with a uniform downward load, or "hot load" of q per unit of length. A fall of temperature of $t°$ below the mean causes an equal uniformly distributed upward load, or "cold load." In either case we have already found

$$q = \frac{2\,\varepsilon\,t\,E_1\,F_0\,v}{l^2\left[1 + \frac{9}{4}\frac{E_1\,F_0\,v^2}{E_2\,F_2\,h^2}\right]} \qquad \text{(VI)}$$

The moment then at any point of the truss due to the temperature load is

$$M_x = q\,l\,x - \frac{q\,x^2}{2} - \frac{q\,l^2}{3} \qquad \text{(XIX)}$$

and the shear at any point is

$$S_x = q\,l - q\,x \qquad \text{(XX)}$$

The strains due to each case of temperature load must be combined with those due to live load, so as to give the greatest possible strains.

Recapitulation of Formulæ Necessary for Complete Calculation of Truss.

For convenience of reference we group here all the formulæ thus far deduced, which are requisite for the calculation of the truss, in the order in which they must be used

$$\text{approx. } F_0 = \frac{(p+m)l^2}{2vf_1}\left(1 + \frac{2v^2}{l^2}\right) \qquad \text{(IX)}$$

$$\text{approx. } F_1 = \frac{(p+m)l^2}{2vf_1} \qquad \text{(IX}a\text{)}$$

$$\text{approx. } q = \frac{2\varepsilon t E_1 F_0 v}{l^2\left(1 + \frac{4E_1v^2}{9E_2h^2}\right)} \qquad \text{(24)}$$

$$\text{approx. } n = \frac{1}{1 + \frac{9E_2h^2}{4E_1v^2}} \qquad \text{(23)}$$

$$\text{approx. } F_2 = \frac{[(1-n)m+q]l^2}{3hf_2} \tag{X}$$

These approximate values, being found, the accurate values are

$$n = \frac{1}{1+\dfrac{9E_2F_2h^2}{4E_1F_0v^2}} \tag{VII}$$

$$q = \frac{2stE_1F_0v}{l^2\left[1+\dfrac{4E_1F_0v^2}{9E_2F_2h^2}\right]} \tag{VI}$$

$$F_1 = \frac{(p+nm+q)l^2}{2vf_1} \tag{XV}$$

$$F_0 = \frac{(p+nm+q)l^2}{2vf_1}\left(1+\frac{2v^2}{l^2}\right) \tag{XIV}$$

For varying cross-section of cable, put F_1 in place of F_0, in (VII) (VI).

We can now find

$$\tau = \sqrt{\frac{E_2F_2h^2}{2kml^2}} \tag{XVIII}$$

where k is given by,
when $a < l$

$$k = \frac{a^3(2l-a)}{2l^4\left[1+\dfrac{9E_2F_2h^2}{4E_1F_0v^2}\right]} \tag{VIII}$$

when $a > l$

$$k = \frac{2l^4-a(2l-a)^3}{2l^4\left[1+\dfrac{9E_2F_2h^2}{4E_1F_0v^2}\right]} \tag{VIIIa}$$

Also

$$H = \frac{kml_2}{2v} \tag{XVII}$$

In these values for k, put F_1 in place of F_0 for varying cross-section of cable.

Knowing now, τ and H, we can substitute their values in

$$\left.\begin{aligned} 2Ae^{\frac{a}{\tau}} - 2ae^{\frac{a-2l}{\tau}} &= -\frac{m}{H} \\ 2\beta e^{-\frac{a-2l}{\tau}} - 2Be^{-\frac{a}{\tau}} &= -\frac{m}{H} \end{aligned}\right\} \tag{XVI}$$

Where

$$\left.\begin{aligned} A &= \frac{1}{2}\left[\frac{R_1}{H\tau} + \left(\frac{2v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau_2}\right)\right] \\ B &= \frac{1}{2}\left[\frac{R_1}{H\tau} - \left(\frac{2v}{l^2} - \frac{m}{H} + \frac{M_1}{H\tau^2}\right)\right] \end{aligned}\right\} \quad (38a)$$

And

$$\left.\begin{aligned} a &= \frac{\tau}{2}\left(\eta + \varphi\right) \qquad \beta = \frac{\tau}{2}\left(\eta - \varphi\right) \\ \eta &= \frac{R_1 - ma + \frac{4Hv}{l}}{H\tau^2} \\ \varphi &= \frac{2v}{\tau l^2} + \frac{2R_1 l - ma\left(2l - \frac{a}{2}\right) + 4Hv + M_1}{H\tau^3} \end{aligned}\right\} \quad (38b)$$

R_1 M_1, H and T being thus found, we can find the deflection at any point from the following equations:

when $x < a$

$$y = \tau^2 Ae^{\frac{x}{\tau}} - \tau^2 Be^{-\frac{x}{\tau}} - \frac{vx^2}{l^2} + \frac{mx^2}{2H} + Cx + D \quad (44a)$$

where

$$C = -\frac{R_1}{H}, \; D = -\tau^2 (A - B)$$

when $x > a$

$$y_1 = \tau^2 ae^{\frac{x-2l}{\tau}} - \tau^2 \beta e^{-\frac{x-2l}{\tau}} - \frac{v}{l^2}(x-2l)^2 + \gamma(x-2l) + \delta \quad (44b)$$

$$\text{where } \gamma = -\tau^2\eta \;\; \delta = -\tau^3\varphi$$

Having thus found y, we can find the moment at any point from the following equations:

When $x < a$

$$M_x = R_1 x - \frac{mx^2}{2} + \frac{Hvx^2}{l^2} + Hy + M_1 \quad (32a)$$

When $x > a$

$$M_x = R_1 x - ma\left(x - \frac{a}{2}\right) + \frac{Hvx^2}{l^2} + Hy_1 + M_1 \quad (32b)$$

Finally, the shear at any point is given by the following equations:
When $x < a$

$$S_x = R_1 - mx + \frac{2Hvx}{l^2} + H\frac{dy}{dx} \tag{33a}$$

When $x > a$

$$S_x = R_1 - ma + \frac{2Hv}{l^2} + H\frac{dy_1}{dx_1} \tag{33b}$$

Where

$$\frac{dy}{dx} = \tau Ae^{\frac{x}{\tau}} + \tau Be^{-\frac{x}{\tau}} - \frac{2vx}{l^2} + \frac{mx}{H} + C \tag{42a}$$

$$\frac{dy_1}{dx} = \tau\alpha e^{\frac{x-2l}{\tau}} + \tau\beta e^{-\frac{x-2l}{\tau}} - \frac{2v}{l^2}\left(x - 2l\right) + \gamma \tag{42b}$$

For temperature load we have

$$q = \frac{2\varepsilon t E_1 F_0 v}{l^2\left[1 + \frac{9E_1F_0v^2}{4E_2F_2h^2}\right]} \tag{VI}$$

Where for varying cross-section of cable we put F_1 in place of F_0.
The moment at any point is then

$$M_x = qlx - \frac{qx^2}{2} - \frac{ql^2}{3} \tag{XIX}$$

and the shear is

$$S_x = ql - qx. \tag{XX}$$

Calculation of Strains.

These are all the formulæ necessary for finding the strains in the truss.

Thus we can first find the temperature strains from (VI), XX) and (XXI). Thus the moment at the centre of any flange, divided by the depth of truss, gives the strain in the flange. A negative moment denotes tension in the upper flange. A positive moment compression.

The shear at any apex multiplied by the secant of the angle which the brace makes with the vertical, gives the strain in the brace. A positive shear acts upward at the left end of the brace. A negative shear acts downward at the left end of the brace.

The strains thus found for temperature load may be of either kind for each piece, according as the "cold load" or "hot load" acts, but in each case is equal in amount.

For the moving load it will be sufficient to take a for a few points of the truss; thus $a = \frac{1}{8}l$, $\frac{2}{8}l$, $\frac{3}{8}l$, etc. For each value of a, find the moments at a few points, such as $x = o$, $\frac{1}{8}l$, $\frac{2}{8}l$, etc. Also the shears. We can then plot these moments and shears to scale. Thus in Fig. 9, we can plot the curves of moments for $a = \frac{1}{8}l$, $\frac{2}{8}l$, etc. Then

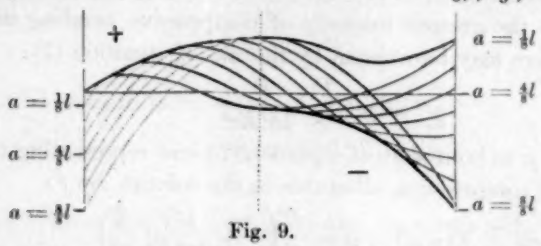


Fig. 9.

at any point the maximum moment will be given by the greatest ordinate at that point to any one of these curves. The curve enveloping them all will therefore give the maximum moments. Thus, in Fig. 9, the greatest positive moment at any point in the right hand half of truss is given by the ordinates to the upper enveloping curve on *right*. The greatest negative moments by ordinates to lower enveloping curve on *right*. The strains in each half are of course the same.

We may treat the shears in similar manner. The maximum moments and shears being found, we can find the corresponding strains as detailed for temperature load.

ADAPTATION OF EULER'S FORMULA TO AMERICAN LONG COLUMN EXPERIMENTS.

By Wm. H. Burr,
Professor of Rational and Technical Mechanics in Rensselaer Polytechnic Institute.

There are some considerations in connection with long column formulæ which frequently escape notice, but which have a very important bearing upon the subject.

Let the following notation be considered:

P = total load, in pounds, supported by column.

S = total area of cross section of column, in square inches.

r = radius of gyration about the neutral axis of the section.

l = length of column in same unit as r.

E = coefficient of elasticity, in pounds per square inch.

Then may Euler's formula become:

$$\frac{P}{S} = p = \frac{4\pi^2 E r^2}{l^2} \text{ (for fixed ends).} \qquad (1)$$

With Hodgkinson's coefficients and exponents this is called "Hodgkinson's Formula."

If p'' is the greatest intensity of compressive bending stress in the column, there may be written, by the aid of equation (1):

$$p'' = p'' \frac{P}{S} \frac{l^2}{4\pi^2 E r^2} \qquad (2)$$

Adding p to both sides of equation (2), and representing the greatest intensity of compression, allowable in the column, by f:

$$f = p'' + p = \frac{P}{S}\left(1 + \frac{p''}{4\pi^2 E} \cdot \frac{l^2}{r^2}\right)$$

$$\therefore \frac{P}{S} = p = \frac{f}{1 + \frac{p''}{4\pi^2 E} \cdot \frac{l^2}{r^2}} \qquad (3)$$

This is the general form of Tredgold's equation. If $\frac{p''}{4\pi^2 E}$ is considered constant and empirical, it is called Gordon's or Rankine's formula, as the latter was the first to introduce the radius of gyration.

Under the gratuitous assumption that $p'' \div 4\pi^2 E$ is constant, it has been empirically determined for different forms of cross section, and inserted in equation (3).

With f determined in a similar manner, equation (3) becomes the long column formula in general use among engineers, and is usually written:

$$P = \frac{f S}{1 + a \frac{l^2}{r^2}} \qquad (4)$$

But it has just been shown that a is *not* a constant, and the preceding operations also show that equation (4), or equation (3), is simply a redundant form of equation (1) or Euler's formula. It would therefore be natural to expect that equation (1) would give results more nearly coinciding with those of experiment than equation (3) or equation (4).

If, however, C is the ultimate compressive resistance of the material, equation (1) becomes inapplicable when $r^2 \div l^2$ is so large that $\frac{P}{S}$ approaches C; or, at the limit, when:

$$\frac{l}{r} \leq 2\pi\sqrt{\frac{E}{C}} \tag{5}$$

For round end columns, the 2 [in equation (5)] is to be omitted.

If, for wrought iron, $E = 28{,}000{,}000{\cdot}00$ and $C = 60{,}000{\cdot}00$ equation (5) gives for flat ends:

$$\frac{l}{r} = 136 \text{ (nearly)};$$

and for round end columns:

$$\frac{l}{r} = 68 \text{ (nearly)}.$$

Hence, it follows that the *coefficients and exponents of* $\left(\frac{l}{r}\right)$, *or* $\left(\frac{r}{l}\right)$, *in equations* (1) *and* (3) *or* (4) *cannot be applied, as they stand, to fixed end wrought iron columns in which* $l \div r$ *exceeds about 140, or to round end columns in which the same ratio exceeds about 70.* Columns with other conditioned ends will fall between these limits.

These limits will exclude a very large portion of the columns used by engineers, and nearly all of those which have been experimentally treated. Below the limits indicated, and possibly far above, therefore, it can only be expected that equations (1), (3) and (4) may give *forms* to which are to be fitted empirical quantities in the shape of coefficients or exponents of $r \div l$, or of the reciprocal of that ratio.

The reason of the failure of the equation (1) below the limit indicated is to be found in the fact that the analytical process by which it is deduced is virtually based on the assumption that the lateral dimensions of the column are indefinitely small, so that whatever may be the length, the condition of applicability always exists.

Let, then, equation (1) be written in the form:

$$\frac{P}{S} = p = y\left(\frac{r}{l}\right)^x; \tag{6}$$

in which y and x are variables.

For other values (r^1 and l^1), of r and l, equation (6) becomes:

$$p^1 = y\left(\frac{r^1}{l^1}\right) \tag{7}$$

Dividing equation (7) by equation (6), then taking logarithms and solving for x:

$$x = \frac{\log.\left(\frac{p^1}{p}\right)}{\log.\left(\frac{lr^1}{rl^1}\right)} \qquad (8)$$

Subtracting equation (7) from equation (6) and solving for y:

$$y = \frac{(p - p^1)}{\left(\frac{r}{l}\right)^x - \left(\frac{r^1}{l^1}\right)^x} \qquad (9)$$

With a sufficient number of carefully made experiments the method of least squares could be used to advantage in the determination of x and y.

The preceding formulæ will first be applied to the results of experiments made on Phœnix columns at Watertown, Mass., and which were published last August in the *R. R. Gazette* and *Iron Age*. The column "Experimental," in table I, contains the mean results of those experiments.

Now let there be taken:

TABLE I.—PHŒNIX COLUMNS.

	Length.	$l \div r$	Experimental. Pounds.	By Eq. (10). Pounds.
Flat End Columns.	28·00 feet	112·0	34,650·00	34,550·00
	25·00 "	100·0	35,150·00	35,000·00
	22·00 "	88·0	35,000·00	35,530·00
	19·00 "	76·0	36,130·00	36,150·00
	16·00 "	64·0	36,580·00	36,900·00
	13·00 "	52·0	37,000·00	37,800·00
	10·00 "	40·0	36,440·00	39,000·00
	7·00 "	28·0	40,700·00	40,630·00
	4·00 "	16·0	50,400·00	43,400·00
	0·66 "	2·7	57,200·00	53,400·00
	25·22 "	68·8	36,000·00	36,570·00
	8·75 "	24·0	42,200·00	41,400·00

$$\frac{l}{r} = 28 \ldots\ldots p = 40{,}700$$

$$\frac{l^1}{r^1} = 112 \ldots\ldots p^1 = 24{,}650$$

Equations (8) and (9) then give:

$x = 0{\cdot}117$; and $y = 59{,}723$ pounds.

Then let there be written:

$$p = 60{,}000\left(\frac{r}{l}\right)^{0.117} \tag{10}$$

The various values of $\left(\frac{l}{r}\right)$ in the table, inserted in equation (10) give the results contained in the last column.

If the experimental results be shown by a curve, it will be seen (as is, indeed, evident from the table) that that corresponding to $l \div r =$ 40·0, (36,440), is abnormally low, while that corresponding to $l \div r =$ 16·0, (50,400) is abnormally high. With these two exceptional cases omitted, the results are seen to be very satisfactory, the greatest divergence existing for the shortest columns. The constants in equation (10) might be so determined as to distribute this divergence more nearly uniformly throughout the range of $l \div r$, but it is thought to be best to place it where it is.

It is both interesting and important to observe that when $r = l$; $p =$ 60,000·00 pounds per square inch; about the ultimate compressive resistance of wrought iron.

The remaining experiments to be examined are those of Mr. Bouscaren on "Keystone and "Square" columns. The latter was a closed box column composed of two channel bars and two plates.

Proceeding in the same manner as before:

For swelled Keystone columns:

$$p = 78{,}000\left(\frac{r}{l}\right)^{\frac{1}{4}} \tag{11}$$

For straight Keystone columns:

$$p = 87{,}000\left(\frac{r}{l}\right)^{\frac{1}{4}} \tag{12}$$

For square columns:

$$p = 303{,}000\left(\frac{r}{l}\right)^{\frac{1}{2}} \tag{13}$$

Table II contains the experimental results of Mr. Bouscaren and the results of the application of equations (11), (12) and (13). The range of $l \div r$ in these experiments is utterly insufficient, and too discontinu-

TABLE II.

	Length.	$l^2 \div r^2$	Experimental. Pounds.	By Eq. (11) or (12). Pounds.		
Flat End Columns.	5·00 feet	326	33,600·00	37,800·00	Swelled.	Keystone.
	15·00 "	2,991	28,800·00	28,700·00		
	27·00 "	9,646	24,100.00	24,800·00		
	15·00 "	3,130	36,900·00	28,500·00		
	27·00 "	9,189	21,100·00	24,900·00		
	27·00 "	9,157	25,400·00	24,900·00		
	27·00 "	8,718	25,000·00	28,000·00	Straight.	
	27·00 "	9,391	27,500·00	27,700·00		
	27·00 "	9,157	30,000·00	27,800·00		
	15·00 "	3,519	30,000·00	31,350·00		
	15·00 "	4,136	32,000·00	30,700·00		
	27·00 "	10,714	27,800·00	27,300·00		
				By Eq. (13)		
	26·00 "	10,414	30,000·00	30,000·00	Square.	
	24·00 "	7,133	33,200·00	33,000·00		
	27·00 "	9,623	30,200·00	30,600·00		

ous for the establishment of a perfectly satisfactory formula; and some of the experimental results are evidently phenomenal. These experiments, however, are the best to be had and will give some idea, at least, of the value of the proposed formulæ. Bearing these considerations in mind the results by formulæ are seen to be very satisfactory.

Reviewing both tables, one cannot fail to observe that, within the limits of the experiments, the formulæ give very close results; much closer, it is believed, than those of any form of Tredgold's equation. The more inaccurate character of the latter, as deduced analytically, is thus confirmed by experiment. The larger values of y and x with increasing values of $l \div r$, as shown in equations (11), (12) and (13), afford also an empirical confirmation of the analytical process, by which Euler's formula is established, as well as the analytical limits prescribed for its applicability.

Success of the Optical Telegraph.—The optical telegraph has succeeded so well in Tunis that the insurgent Arabs are now unable to interrupt the regular correspondence between the different corps of the French army. The same system is also employed in Algiers.—*Les Mondes.* C.

THE FLANNERY BOILER-SETTING FOR THE PREVENTION OF SMOKE.

By CHARLES A. ASHBURNER, Philadelphia.

Read at a meeting of the American Institute of Mining Engineers, October, 1881.

The appliances which have been proposed, and the modifications in the construction of boiler-furnaces which have been made for the prevention of smoke, and the utilization of what are ordinarily called the waste products of combustion, have been innumerable.*

The Flannery boiler-setting, which I wish briefly to describe to the members of the Institute, contains probably no one new original device; but it is rather a new combination of parts which, in its practical working, effectually prevents smoke from being thrown off from the chimney, and utilizes the heat units contained in the products generally lost. The quantity of fuel required to produce a given result is, in consequence, reduced.

As early as 1858 one hundred and three different plans of boiler-furnaces for the prevention of smoke were submitted at one time to the Steam Coal Collieries' Association, New-Castle-upon-Tyne. In a report upon these plans made by Messrs. Longridge, Armstrong, and Richardson, the furnaces were divided into seven distinct groups, according to the principles involved in their construction. The plans which have been proposed since 1858 have been, in most cases, more practical, more economical, and more efficient applications of the same principles.

The products of the combustion of bituminous coal, on a simple furnace fire-grate, are generally considered to be steam, carbonic acid, carbonic oxide, and soot. Of these, the first two are incombustible, the last two combustible. To these four products may be added the nitrogen of the air.

In cases, even where the draft of air through the grate-bars is not excessive, there is a certain amount of unconsumed oxygen which passes through the boiler flues with the products of combustion. Abso-

* An exhibition was lately held in London "of apparatus of all kinds devised to prevent smoke."

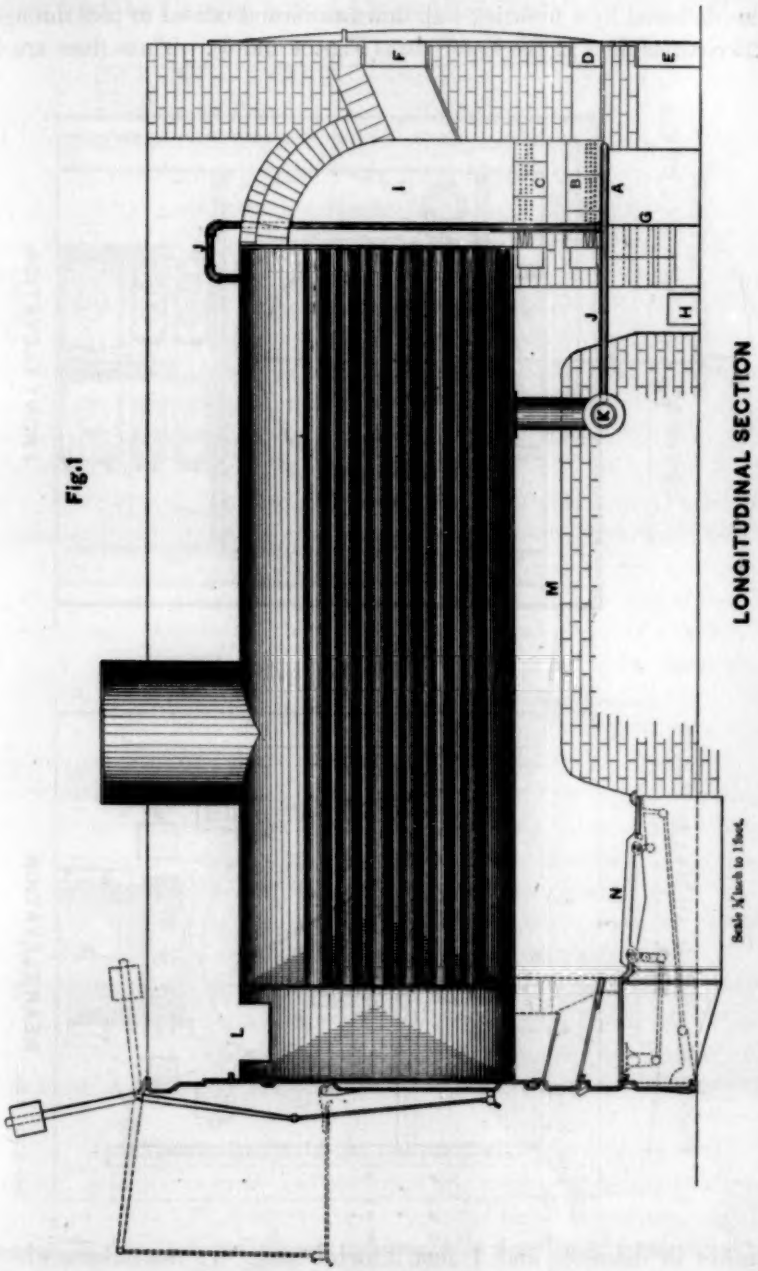
lutely perfect combustion of bituminous coal produces only steam and carbonic acid. The more nearly a furnace approaches this result, the more efficient is it in economizing fuel and in the prevention of smoke, or, more strictly speaking, soot, which is the solid carbon contained in smoke.

The economy of combustion in the Flannery furnace lies in the fact that the soot and carbonic oxide (which pass off through the chimney of an ordinary furnace) are almost entirely converted into carbonic acid before leaving the boiler flues. It is not my purpose to claim for this furnace the greatest economy of construction or duty, or even to make comparisons with other furnaces or boiler-settings which have been devised to accomplish the same end, but merely to describe a boiler-setting which, by experience, has been found to be practical and economical, and which seems to accomplish all that the designer claims for it. It is impossible for me to state in precise terms the value of the increase of heat obtained. As a rule, practical results differ so widely from theoretical computations that they can best be made after the determination of empirical values. The most important results to be noted, where this furnace is at present being used, are: The total absence of smoke where a dirty and highly bituminous coal is being consumed, a total saving of about 33 per cent. of the coal required in an ordinary boiler-setting with the use of the same boiler and engine, and a great saving in the labor required to keep the flues clean.

The front portion of the furnace may be constructed after any of the ordinary designs which are applicable to a plain cylinder, cylinder-flue, cylinder-tubular or the other general forms of steam boilers in common use. The boiler which is illustrated by the accompanying drawings is an ordinary cylinder-tubular boiler which is being erected at Beloit, Wisconsin, for the Rock River Paper Company.

The most important points to be noted in this boiler are: The gas-flues at G (Fig. 1), where the temperature of the products is equalized; the secondary grate, A, with incandescent coals through which the products are passed, and the air-ducts, C, above this grate, where heated air is introduced, whereby combustion is completed in the chamber I.

After combustion has taken place at the front grate, N, the products resulting therefrom pass under the boiler and over the bridge-wall, M. At the rear end of what is called the combustion-flue, and a short distance (about 1 foot) back of the end of the boiler, the gases and soot


F
D
E
C
B
A
I
G
J
H
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M
N
L
LONGITUDINAL SECTION
Scale ¼ inch to 1 foot.

Fig. 1

are deflected by a firebrick wall downwards and caused to pass through 25 circular flues in the lower part (Figs. 4 and 5). These flues are 3

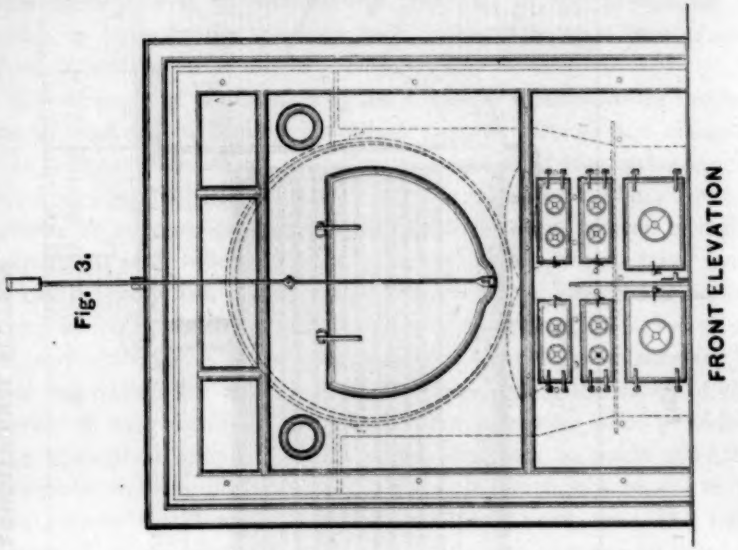


Fig. 3.

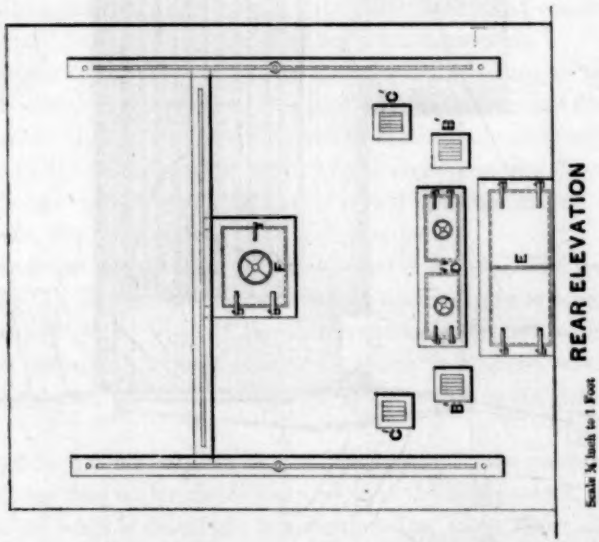


Fig. 2.

inches in diameter and 1 foot 3 inches long. In the furnace which

has been working for some time at Akron, Ohio, there is but one large

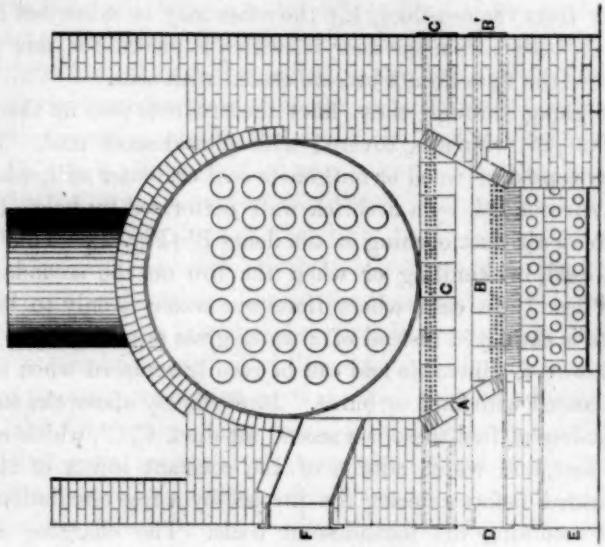


Fig.5. CROSS SECTION WITH TILE GRATE DOORS ON THE SIDE

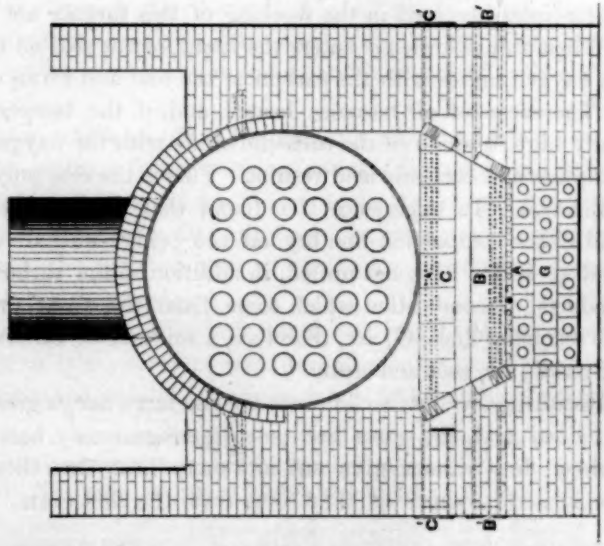


Fig.4. CROSS SECTION WITH WATER GRATE

opening in this wall, but the substitution of a number of smaller flues

is thought to be a decided improvement. The flues are cleaned when necessary from the ash-door, E; the ashes may be taken out from the door E or, better, from the door H, which is placed for this purpose. In practice the flues do not become coated with soot.

After going through these flues the products pass up through the water-grate, A, which is covered with incandescent coal. The fuel here may consist of wood or anthracite coal or, better still, coke. The grate is surrounded by a firebrick wall perforated by holes, B, which lead into an air-duct opening at the doors B′ (Fig. 2). This air-duct is only used in kindling or when the fire on the secondary grate becomes dead. In cases where limestone water is only to be had, a tile-grate is employed instead of a water-grate (see Fig. 5). The latter is, however, adjustable and can be readily replaced when the pipes become coated with lime or burnt. Immediately above the surface of the incandescent fuel there is a second air-duct, C, C′, which is similar to the first, and which admits of the constant influx of air. The air is heated before entering the furnace by a free circulation around the wall confining the incandescent coals. The charging door for this grate is at F; I is the combustion-chamber, from where the ultimate products pass through the boiler-flues and are carried off by the chimney located at the front end of the boiler.

The principles involved in the working of this furnace are familiar ones. When atmospheric air enters the incandescent coal on the front grate its oxygen unites with the carbon of the coal and forms carbonic oxide. The excess of air becomes heated and, if the temperature is sufficiently high, a union of the carbonic oxide with the oxygen of the air takes place and carbonic acid results. This is the case only in perfect combustion. In experience it is found that the gases above the grate and in the combustion-flue beyond the bridge-wall are carbonic oxide and air which have not united, in addition to the carbonic acid. The products of combustion which come from the front grate and enter the restoring flues, G, are, therefore, a mixture of carbonic acid, carbonic oxide, air, soot and steam.*

In substituting a number of flues for one large one, a greater surface is gained and the gases are more homogeneously heated. Of course these flues cannot give out any more heat than they absorb from the heated products as they come from the first grate. As the

* Nitrogen is not considered, as it does not directly affect combustion.

heat of these products is variable, due to firing and other causes, the heat of the flues will be an average of the heat of the products, and the gases as they enter the ash-pit of the second grate will have a more uniform heat than before entering the flues. When these products enter the incandescent coal on the second grate the carbonic acid unites with a portion of the carbon of the fuel and forms carbonic oxide. This is a direct loss of heat units.* The heat, however, is regained by the carbonic oxide thus formed uniting with the oxygen of the air introduced through the ducts C, C′, and carbonic acid results. The carbonic oxide which comes from the front grate is raised above the point of ignition by the incandescent fuel and unites with the oxygen of the introduced air and forms carbonic acid. The excess of atmospheric air enters the coals on the second grate and undergoes the same conversion as that which took place with the air entering the first grate. The particles of carbon, forming the soot from the first grate, are raised to incandescence and, uniting with the air from the ducts C′, C′, form carbonic acid.

The steam is decomposed in passing through the coals on the second grate, the oxygen uniting with the carbon forming carbonic oxide which is afterwards converted into carbonic acid above the surface of the coals. The liberated hydrogen unites with the oxygen of the air introduced through the ducts C, C′, and again forms water. The ultimate products resulting from combustion in the Flannery furnace are thus carbonic acid, steam and a small amount of carbonic oxide,† but no soot.

The gases which go off in the chimney are of a higher temperature than in an ordinary furnace-setting, and this fact very materially assists the draught. At the Akron Water-works the chimney is erected at the rear of the boiler and, although the gases are returned from the smoke-arch the entire length of the boiler, a sufficient draught has always been maintained.

A number of the Flannery furnace-settings have been constructed and, after a trial extending over several months, have produced more than anticipated results in economizing fuel, in the consumption of

* One pound of carbon in burning to carbonic acid gives out 14,500 heat units, one unit being the amount of heat required to raise one pound of water from 39° to 40° Fahrenheit. The same amount of carbon in burning to carbonic oxide gives out 4400 units.

† If the furnace is properly fired and the draft properly regulated, all the carbonic oxide should be converted into carbonic acid in the combustion-chamber, I.

soot and consequent prevention of smoke, and in a reduction in the labor, especially in that required to clean the flues.

At the Akron Water-works, recently constructed, two tubular boilers, 5 by 18 feet, with 64 4-inch flues each, have been set on the Flannery system. Two Worthington pumps have been erected, one a compound high pressure, the other a compound condensing, Up to the present time the high-pressure pump and one boiler have alone been in service. The facts which have been noted in regard to the efficiency of the furnace have been very general, but they are such as to indicate its economy. The furnace has been fired, day and night, for eleven days, with 14 tons of a dirty, bituminous slack coal, which is mined in the vicinity of Akron and sold at the works for $1.00 per ton. On the second grate Connellsville coke has been used, costing $6.00 per ton. For every ton of coal burned 300 pounds of coke have been used, the coke costing $0.90 per ton of coal consumed. The total cost of fuel for eleven days was $26.60.

The reservoir attached to the works is 210 feet above the pumps and 2700 feet distant. The consumption of water has been about 1,000,000 gallons per diem. To do the same work the boiler with the usual setting would have required at least 35 tons of coal, at a cost of $35.00.

The average saving which would result in most cases from the use of the Flannery furnace would undoubtedly be greater than that shown at Akron, where the coal used is very poor and the cost exceptionally low. At Akron local conditions made it necessary to return the gases from the smoke-arch to the rear of the boiler where the chimney is located, through a flue 40 inches square and 27 feet long. This is considered to be a disadvantage. I am informed by the superintendent of the works that the labor required to run this boiler is one-half of that which is ordinarily required with the usual setting.

The advantages which are claimed for this boiler-setting are: Economy of fuel and prevention of smoke, economy of labor, more even action of the boiler and its longer continuance in service, due to the small amount of deposits in the flues.

The system is particularly applicable in the setting of boilers where continuous service is required, where the cost of the fuel is great, where the space occupied by fuel is valuable or where the production of smoke is objectionable.

MILK.

By Reuben Haines.

[A Lecture delivered at the Franklin Institute, February 27, 1882.]

Milk, as we all know, is one of the most important foods of man, more especially, because it constitutes usually the exclusion food of the infant during the first few months of its life, and the most important constituent of its food for a year or two afterwards. We should also consider that, from childhood all through life, it is still largely used as a very desirable constituent of a multitude of culinary preparations and as an occasional drink. Statistics gathered from London, Paris, Königsberg, and Munich show the average daily consumption of milk per head of the whole population to be ½ pint or one tumblerful—butter, ⅝ oz., cheese, ⅓ oz.

The milk yielded by the whole class of mammalia or suckling animals is essentially the same in its constitution—it contains the same substances in all but in varying relative amounts.

The opinion used to be prevalent that milk in its origin was simply an exudation of the blood, and derived directly from it either by filtration through the membranes of the blood vessels, or by a selective power exerted by the mammary gland on the materials of the blood. This, however, is now considered untenable. The researches of Fürstenburg and Voit have shown that the constituents of the blood are first utilized in the formation or building up of the cells of the milk glands, in other words, the breasts of the animals—they go to form flesh. Then milk is formed from this by its decomposition or destruction through what is termed the fatty degeneration of the cells of the mammary gland, the sweat glands of the skin and the general metamorphosis of their contents. In this manner the solid constituents of milk are formed, while the water of the blood simply percolates through the tissues into the milk. Against the theory of the milk being directly derived from the blood may be instanced two facts, namely, that casein or cheese and milk sugar are not constituents of the blood, and hence must be formed by a special action of the milk glands; and secondly, the composition of milk does not vary like that of the blood according to different kinds of food digested by the animal. Milk has a tolerably

constant composition through all the changes of food of different kinds, but of similar degree of nutritiousness. Thus, for example, it has been found by G. Kühn, that the quantity and quality of cow's milk will vary according to its richness, or otherwise, in nitrogenous substances in general, but an increase of fat or oil or of sugar in the fodder has no influence upon the quantity and quality of the milk, and it is found impossible simply by alteration of food to increase one constituent of the milk over another.

In support of the more recent theory of milk formation just stated, we have the fact that the milk present, shortly before and after birth, is found by the microscope to contain cells undergoing decomposition. This is called the colostrum, and is regarded as an imperfectly formed milk. A somewhat similar milk is secreted during some acute diseases.

Dr. J. König,* of the agricultural experimental station at Münster, in Wiesbaden, from whose recent work on foods and drink I have largely drawn for this lecture, thus defines "milk as cell-structure made fluid, and every suckling animal as a carnivor which consumes the milk-gland organs formed out of the blood of the suckling mother."

The chief constituents of milk are water, casein, albumen, fat, milk-sugar and salts.

The water varies in single animals between 80 and 90 per cent., depending in one and the same species upon individuality and the maintenance of food in quantity and quality.

The group of nitrogenous substances comprise especially true casein and albumen. Both of these together, with one or two other similar substances, are classed under the collective term of casein. The coagulation of the casein produces the curdling of milk and forms the curds or cheese. The cause of the spontaneous coagulation of casein has long been a matter of dispute. Hammersten, of Upsala, has shown that the casein coagulated by acids has different properties from that coagulated by calf's rennet. He also regards that action produced by rennet to be due to a special ferment existing in the latter and capable of taking place in the complete absence of either milk-sugar or lactic acid. The phosphate of lime existing in the milk appears to have an important influence in causing the coagulation. Hammersten believes the ferment causes the casein to split up into two separate forms, one of which is insoluble in a solution containing phosphate of lime, while the other remains in solution. W. Kirchner, in a work published in

* Die menschlichen Nahrungs- und Genussmittel. Von Dr. J. König, Berlin, 1880.

Dresden, in 1877, considers Hammersten's soluble modification of casein as identical with peptone, and he thinks that the difference in digestibility noticed between human milk and cow's milk is owing to the varying proportion of peptone in any given milk. Some authorities believe the difference in digestibility to be owing to the fact that the casein of cow's milk coagulates in large flakes while that of human milk occurs in small flakes.

The casein is not in true solution, or only partly so, according to Hoppe-Seyler, etc. The fat of milk is essentially the same thing as butter. It occurs in milk in the form of minute globules to which is due the color and opacity of milk. On standing at rest for some time, these fat globules being of lighter specific gravity, rise to the surface and form the cream. The opinions of eminent authorities are divided upon the question of the exact condition in which the fat occurs in milk. Some believe the milk globules are surrounded by an envelope of casein, while others hold that no envelope of casein exists at all, but milk is a true emulsion of the fat. Soxhlet has made numerous experiments which are decidedly favorable to the latter hypothesis. The fat of milk, like butter, is composed chiefly of three fatty substances with minute amounts of some volatile fatty acids.

Milk sugar occurs in human milk and in the milk of herbivorous animals. It forms hard glittering crystals of a slightly sweetish taste, soluble in 6 parts of cold and 2½ parts of boiling water.

The ash or mineral salts of milk are chiefly phosphates and chlorides of lime, potash and soda, with a little magnesia and iron, in which the phosphates of potash and lime predominate in cow's milk. In some cases sulphates are found in natural milk.

The following is the average composition of the milk of different animals.

	No. of Analyses.	Water.	Casein.	Albumen.	Fat.	Sugar.	Salts.
Human milk,	190	87·09	0·63	1·31	3·90	6·04	0·49
Cow's "	300	87·41	3·01	0.75	3·66	4·82	0·70
Goat's "	70	86·91	2·87	1·19	4·09	4·45	0·86
Sheep's "	16	81·63	4·09	1·42	5·83	4·86	0·73
Lama "	3	86·55	3·00	0·90	3·15	5·60	0·80
Camel's "	2	86·94	3·84		2·90	5·66	0·66
Mare's "	27	90·71	1·24	0·75	1·17	5·70	0·37
Asses' "	17	90·04	0·60	1·55	1·39	6·25	0·31
Swine "	9	84·04	7·23		4·55	3·13	1·05
Dog's "	16	75·44	5·53	4·38	9·57	3·19	0·73
Cat's "	1	81·63	3·12	5·96	3·33	4·91	0·58
Elephant* "	3	67·85	3·45*		19·57	7·33*	0·65

* Average of two analyses. Casein and sugar in average of three analyses, 11·93 per ct.

Of these analyses, of course, the chief interest lies in those of human milk and cow's milk, but goat's milk is also, as we know, used as food to a considerable extent. The latter differs from cow's milk chiefly in containing much more fat, which sometimes reaches a maximum of 9 per cent. It has, however, a peculiar taste, which renders it unpleasant to many persons. Its casein coagulates in large clots. Sheep's milk is interesting as being the material from which Roquefort cheese is made. It is one of the most dissimilar from human milk, but is used for human food in montainous regions, as in the Apennines, Carpathian mountains, and also in Holland. Camel's milk and mare's milk are used by the Kirgis and Tartars to make their koumiss. Asses' milk is used in France, as a substitute for human milk for children. It approaches most nearly to human milk in composition, but less rich in fat and is more watery. Carnivorous animals, such as the dog and cat, yield milk richer in nitrogenous substances, and quality of the milk is also more influenced by the kind of food than is the case with herbivorous animals. Elephant's milk, which was obtained for the first time last year, is given as a curiosity for its enormous richness in fat, approaching to the condition of cream. It is also rich in sugar.

Inasmuch, however, as cows milk is in this country at least almost the only commercial milk, and hence, the only milk practical as a substitute for human milk, we will confine our attention to the consideration of these two kinds.

On comparing the composition of human milk and cow's milk, we find the following differences. (J. König.)

Human milk has a slightly alkaline reaction to test paper, while cow's milk has a reaction which is described as both slightly alkaline and slightly acid at the same time, and soon becomes distinctly acid.

Human milk contains more albumen in proportion to the casein. It contains more sugar and has a sweeter taste. Its fat globules are larger, about double the average size of those in cow's milk. Its casein is coagulated by the acid of the gastric juice in small finely-divided flocks, while that of the cow coagulates in larger flocks.

In regard to the mineral ingredients or ash cow's milk is poorer than human milk in chloride of potassium, but richer in phosphate of lime.

Human milk varies very greatly in its richness in fat. In 190 analyses the fat varied from 1·71 to 7·60 per cent. In some cases the fat is less than 0·50 per cent., especially after a long fast as just before breakfast. The general richness of milk is dependent upon the

richness of the food, but the variations from this cause occur more in the fat and sugar than in the nitrogenous substance.

The percentage of ash is subject to great fluctuation, probably partly owing to the particular kinds of food, for a slight increase of chlorine and sodium is noticed when common salt was added to the food. Nevertheless, there can be no doubt, from actual analysis, that human milk is subject to greater fluctuations in composition than in the case of animals. It is also well known that the emotions, such as fear, anger, grief, etc., affect both the quantity and quality of human milk, as is shown by actual experience.

In an analogous manner but in a less degree the composition of cow's milk varies according to different circumstances.* Among them may be named the age of the cow; its race or breed; the number of previous calvings; time from last calving; time of day when milked; whether stall-fed or at pasture; if stall-fed, the kind and quantity of fodder; whether the sample was from the first part of the milking of any one cow or from the last part of the same, or in other words, from the "fore milk" or the "strippings," or, whether the sample was taken from the whole of one milking of any one cow previously thoroughly mixed; the general condition of health of the cow; cleanliness, warmth and ventilation of stable. In addition to these there appears to be what the Germans call individuality or idiosyncracy, by reason of which cows of the same breed have different individual peculiarities of milk even when under the same conditions in other respects. This peculiarity is analogous to the quality observable in men who remain lean and thin, or become corpulent, independent of the kind and quantity of food, and even when efforts are made to produce a contrary result. In man, however, as we know, such peculiarities are often inherited and are then of the nature of race characteristics.

The influence of race upon quality of the milk is shown by the following analyses by O. C. Wiggin, of Providence, R. I. (Johnson's Encyclopædia, art. Milk by C. F. Chandler.)

	Water.	Solids.	Fat.	Casein.	Sugar.	Salts.	Sp. Gr.
1. Alderney,	83·04	16·96	8·07	5·02	3·05	79	1·030
2. Alderney,	83·93	16·07	8·28	3·14	4·02	63	1·029
3. Durham,	84·56	15·44	6·41	4·35	3·97	68	1·033
4. Ayrshire,	86·60	13·40	3·70	4·76	4·35	59	1·031
5. Devon,	84·71	14·29	3·96	5·29	4·23	81	1·033

* Gorup-Besanez—"Physiologische Chemie;" J. König—"Nahrungs- und Genussmittel."

The first was made in January, all the rest in June. These I suppose to be single analyses, not averages.

An analysis of my own of the mixed milk of two Alderney cows (part Durham) made in December.

Water.	Solids.	Fat.	Solids not Fat. Casein, Sugar and Ash	Ash.	Sp. Gr.
84.17	15·83	5·53	10·30	·68	1·0321

The sample was taken at a time when the milk was much less rich than it had been during the summer months.

In regard to the time elapsed from calving it has been found that with the continuance of the same food, after some time the dry solids and nitrogenous substances, viz., casein, will gradually increase and the fat and sugar decrease. By giving a richer nitrogenous food this falling off in fat and sugar will be delayed for a much longer period.

Evening milk is generally richer in fat than the morning milk, while the other constituents remain about the same, as shown by the average of analyses conducted for a whole year by a number of chemists. Baumhauer did not find this the case at all constantly, however, in his analyses.

The milk first drawn from the udder will very frequently be very deficient in fat, in some cases almost entirely wanting in it,* while the last which is drawn is very much richer in fat than the average. The other constituents remain nearly the same. Hence, it is very important to mix all the milk of one milking before it is served to customers or an analysis made of it; otherwise, some get poor milk and others rich milk from the same cow. Two cases are on record in which milkmen tried to throw discredit on a chemist's analysis by sending him samples from the first quart of the milking.

From all that has been said, we will perceive that cow's milk has naturally quite a variable composition. It is this fact that has been one of the chief obstacles in the detection of adulteration in the commercial article. That milk is subject to considerable adulteration is a notorious fact. The kind of adulteration practiced is usually that of watering the milk, and of robbing it of the cream by skimming. The mixing of foreign substances with the milk has occasionally been detected, but is probably of seldom occurrence. The methods of watering and skimming being, however, so easily practiced at the dairy,

* *Vide* A. W. Blyth—"Foods and Poisons," London and New York, 1879.

and the necessity of employing milk agents for city supply render the temptations to it very great.

Every family ought to be able to obtain pure and wholesome milk, more especially on account of its forming the chief part of the food of young children. Yet many people in large cities find it impossible to obtain milk in a satisfactory condition, and many more are ignorant of the poor quality of the milk served them. From one point of view the real importance of the question turns upon the concealment of the impoverishment of the milk, and the palming off of a poor article of food for a good one, constituting a fraudulent depreciation of the value of one of the necessaries of life. Those who know its real value can provide accordingly. They will take more of it, if it is poor or make up the deficiency with other food. If they pay the usual price of good milk they do not get the full value of their money, bus the fault in that case is, partly at least, their own, for they purchate knowingly a poor article at a high price. But a mother who is ignorant of the fact that half of the nutritive substance of the milk has been abstracted may be starving her child without knowing it. It may become sick and wasted, yet she may not know that this is the cause. It is well known to medical men that one of the chief dangers to children under one year of age, among the poor in large cities, is death from *want* of sufficient nourishment. Yet the poor will be tempted to buy the poor article knowingly, but are ignorant of the disastrous consequences.

Now in what way can we most readily and accurately know the true condition of any milk? By what means can we detect adulteration in such a manner as to convict the offender? Upon this point, unfortunately, there is much difference of opinion, and owing to these differences the guilty party frequently escapes, even from the court-room. Many cases, also, of minor degrees of adulteration, are never brought to trial, because of the great uncertainty of obtaining conviction. One of the chief of these difficulties lies in the uncertainty existing as regards an absolutely fixed standard for pure unsophisticated milk. We have but to consult the records of very numerous analyses published in manuals on this subject to find such wide variations as apparently to put such a standard out of the question. Many hundreds of such analyses have been made and an average composition has been calculated from them, and this is proposed by many as the proper standard; but as many cases of pure milk will necessarily fall below this average,

others contend that the standard by which to establish adulteration must be low enough to include the poorer grades of natural milk as pure, so that injustice shall not be done to innocent dairymen who may happen to have cows of poor stock. But placing the standard so low will thus enable unscrupulous milk-men to water a rich quality of milk to the extent of ten or twenty per cent. without risk of legal penalty.

Differences in the richness or in other words the composition of the milk, which I have brought to your notice, have their influence upon its specific gravity or its weight as compared with that of distilled water. Statements have been published that the specific gravity of pure milk from single cows may vary all the way between the limits of 1·016 and 1·040, but it usually does not vary more than from 1·027 to 1·034, while skimmed milk has a specific gravity of 1·035 to 1·038. Average good milk mixed with half its bulk of water has, on the other hand, a specific gravity of 1·016. Inasmuch, then, as the specific gravity is the test which is often chiefly relied upon and placed in evidence in law suits, the importance of this variability becomes very obvious.

The real source of this perplexity is probably to be found, however, in the confounding of the composition of the milk from single cows with that of the mixed milk from large herds. A knowledge of the former is necessary to arrive at facts in physiological science, but the latter is the only one with which the milk inspector has to concern himself in most cases, especially in commercial or market milk. This view has lately been advanced in forcible language by Oscar Dietzsch, analyst in the canton of Zurich, Switzerland, and author of a recently published manual on adulteration of food.* He states, that if care is taken to select unadulterated mixed milk from large herds, the variations in specific gravity and composition will almost wholly disappear. The differences above and below the average will, in fact, neutralize each other to a great extent, and the specific gravity will vary only between 1·029 and 1·031. Mr. Dietzsch also states that if great care is taken to preserve the cows in a normal state of health this variation will be still less, standing at 1·030 to 1·031.

From these facts he declares, substantially, that all milk from large herds or such mixed milk as is usually sold in cities, which has a specific gravity, either above or below these figures, viz., 1·029 and

* Die wichtigsten Nahrungsmittel und Getränke und deren Verfälschungen. Von Oscar Dietzsch. Zürich, 1879.

1·031, has been adulterated, or manipulated so as to be practically the same as adulterated. This conclusion being granted as correct, the testing of milk would seem at first sight to be an easy task, being done by men by plunging a suitable hydrometer into the milk and noting the mark to which it sinks. This would be a correct method if all the solid constituents influenced the specific gravity in the same way. In reality, while most of these tend to increase the specific gravity, the fat, which forms the most important part of the cream, tends to lessen it, or to make the milk lighter in weight. Hence arises an important complication, for if you by any means lessen the proportion of the other solids the hydrometer sinks, but on lessening the fat the hydrometer rises, and consequently by lessening both the fat and the other solids in the proper proportion, you can make the hydrometer stand at the same mark which it did in the original pure milk. The easiest way to lessen the proportion of total solids, which are heavier than water, is to add water to the milk and this will bring down the specific gravity nearer to the mark for pure water, but the fat being itself lighter than water tends to keep the specific gravity down, and consequently, if a considerable part of it be removed, the specific gravity will again aise in proportion as more fat is removed from the milk. This is practically what very many milk-men do, for it is a common circumstance for the milk-man to remove a part of the cream, either by skimming off the cream or by setting aside for milk the first part of the milking of each cow, which is poor, and putting in other pans the strippings, which he sells separately at a higher price and thus secures a double profit on his milk; but by doing this he abstracts a part of that which makes the milk lighter and leaves the milk with a higher specific gravity than should be the case with pure fresh milk. This is readily detected by the hydrometer. The knowing milk-man, however, now adds sufficient water to the milk to bring down the specific gravity to the normal point for the pure unadulterated article. He has now doctored the milk in two ways, both of which yield him a profit, and yet the hydrometer or lactometer, as it is called, will not, when used alone, indicate any adulteration whatever. It is true that the milk will be apt to look thin and poor, unless it was originally quite rich, and hence, a practiced eye might readily suspect it; but it is well known that persons unaccustomed to first-rate milk would take it without any complaint.

It is, however, possible for the milkman to avoid detection by

ordinary customers by adding some substance which will thicken the skimmed and watered milk and give it the proper color. Carbonate of soda, starch and sugar, and various coloring substances are said to have been sometimes used for this purpose. According to Baumhauer, it was customary in Holland, some years ago to use the yellowish dirty water of the canals for mixing with the milk, and at the same time give it a creamy color. The usual way in which the milk is skimmed is by taking off all the cream at night and adding the skimmed milk to the fresh morning's milk. It is thus half skim, and is composed of old and new milk mixed. Such milk is very difficult to keep in warm weather, often becoming sour almost as soon as delivered, and is therefore injurious to very young children and particularly to infants.

Another instrument which is largely used for testing milk is the cremometer, consisting of a simple graduated cylinder glass or tube, into which the milk is poured, and after a suitable time the amount of cream which has risen to the surface is measured. Although of some practical use in estimating the value of a cow for butter-making, there are many serious objections to its use in ascertaining the purity of market milk. Unless used with the most scrupulous scientific care, and also even then, it will give uncertain and varying results, so as frequently to be very misleading. The same milk will yield different amounts of cream in the same fixed time, after having been subjected to different degrees of shaking or agitation before being poured into the cremometer, the extent of variation being from six to ten per cent. Therefore, the same milk will be apt to yield different amounts of cream at the market and at the dairy. The temperature to which it has been exposed while standing in the cremometer has considerable effect on the amount of cream. Different milks containing the same amount of fat require different lengths of time to yield approximatively the same amount of cream. This is owing to the fact that some milk contains a greater proportion of large fat globules, which rise more quickly than the smaller ones. The milk of the same cow gave by the cremometer 9 per cent. of cream in the morning, and 12 per cent. in the evening of the same day, while the variation of the fat was found by analysis to be only one-tenth of one per cent. The milk of two different cows gave each 10 per cent. of cream by the cremometer, while the fat contained in one of them was found by analysis on the same day to be one-third greater than in the other. In each case great care was taken in regard to handling the milk, and the

cows were placed under the same conditions. These facts have been clearly set forth by Baumhauer, in a paper on this subject, *American Chemist*, November, 1876. To this we may add the fact that cream itself is of greatly varying composition, a rich cream containing often three times as much fat as a poor quality of cream, and hence the volume it will occupy in the cremometer will vary also. It is well known that the skim milk of a rich quality of milk, such as that of Alderney cows, is of poorer quality than ordinary skim-milk (so far as the fat is concerned), because a much larger proportion of the fat is in large globules, all of which with considerable part of the smaller globules rise to the surface and form the cream.

In fact without going into further details the volume of cream yielded by a milk in a given time is by no means an accurate measure of its richness. If the cremometer does not give trustworthy results by itself, it is surely of little use in combination with the lactometer, although this is recommended by some authorities.

Other instruments have been devised for finding the amount of fat in the milk by the eye and judging the purity thereby, but they are all open to serious objections. That which is most highly recommended is the lacto-butyrometer of Marchand and Salleron. I shall not describe it here but will state that Marchand himself admits that when it gives negative results, inspectors "should take care to have the suspected sample examined by an expert chemist. This is a measure of prudence from which they should never depart."* He thus confesses the insufficiency of his process, and it is still to be discovered whether it has any advantages over the ordinary lactometer.

In regard to the lactometer again, other circumstances besides adulteration may lead to false conclusions, especially when the mixed milk of only a few cows is examined. Ordinarily we expect a milk rich in cream to have a low specific gravity, but the casein and sugar may also be so largely increased as to counterbalance the effect of the fat, and then notwithstanding its large amount of cream it may have a specific gravity closely approaching that of skimmed milk. The eye, however, will at once perceive the difference, and an inspector with his eyes shut does not know his business.

Theoretically, the only reliable test is a chemical analysis of the milk, but there are several practical objections to its use on a large scale. For such a work a trained chemist is necessary, considerable

* H. A. Mott—"Adulteration of Milk," 1878.

length of time is required for each analysis, and the expense is, therefore, heavy. Although a large number of samples may be analyzed, at the same time none of them can be completed in less than five or six hours. It is, therefore, impossible to test milk by this means just at the time and place where reliable testing is the most needed—at the dairy or milk depot before the milk is allowed to go out to customers.

Yet we may dispose of this last objection, partially at least, if we allow the milk from which samples have been taken for analysis to pass unchallenged until the following day and so also on each succeeding day. Of course, if milk is adulterated with anything injurious, we run the risk of its doing some harm. But the chances of this occurring on any one day are so exceedingly small, even if we take into account the liability of watered milk containing "germs" of disease from polluted water, that this objection may be entirely ignored. The question of expense is a much more serious obstacle, yet this also may be lessened very materially by thoroughly systematic arrangements of the laboratory, conditioned, of course, on regularity and constancy of work to be done.

One method of avoiding the chances of failure of the lactometer to indicate adulteration is a cursory examination of each sample of milk under the microscope, and an approximate estimation of the number and size of the fat globules in the field of view at one time. The instrument need not be expensive, and a little practice would enable any one to become expert at such examination.

As has been stated the adulteration of milk consists almost exclusively in the addition of water and the partial removal of the cream. The former is clearly adulteration in the ordinary use of the word, but the latter is also now technically strictly an adulteration, for that term now legally includes the abstraction of any valuable constituent of food.

The watering of milk is not only a fraud, but is really a practice which has several times proved very dangerous to health. For the farm yard is, as a rule, not over clean, and the dairyman in total ignorance of some very important sanitary rules, often places his pump in very close proximity to the common privy or dung-heap, or takes the water for dairy purposes from a brook which is polluted directly with sewage. A number of epidemics of typhoid fever in England, which have been traced directly to the milk supplied from certain farms where typhoid fever was found to exist, give ample and convincing proof of this danger.

These epidemics of typhoid fever in England, in which the evidence of the cause being polluted milk was very strong, were as follows: The epidemic at Islington recorded in 1870; Penrith, in 1870; at Mosely, near Birmingham; at Leeds, in 1873; at Armley, near Leeds, in 1872; at Glasgow, in 1873.

Scarlet fever may also be communicated through milk. This occurs not by any adulteration, but carelessness in allowing persons having the symptoms of an eruptive disease to milk the cows, and scabs from the skin of such persons get into the milk and remain there as an active poison. Unquestionable cases of this kind have occurred recorded by Prof. Bell, of St. Andrews, and Dr. Taylor, of Penrith. An outbreak at South Kensington, London, was traced to cream.

While such dangers as these, which affect older children and adults, are of sufficient importance for our careful consideration, the chief importance of this whole subject of milk and its adulterations lies in the fact that cow's milk is the peculiar and often predominating food of very young children, and this importance comes out still more forcibly, in view of the fact of the great mortality among children under five years of age, in all large cities, and the still greater mortality among infants of less than one year old. It is very true that a large part of the mortality of infants is due to intense summer heat at a period of life when the sweat glands of the skin have not yet developed their proper functions so as to lower the temperature of the surface of the body by the perspiration and also the want of movement in the air and the crowding together in small rooms. But it is also true that improper and insufficient food causes the death of very large numbers of infants of the poorer classes.*

By the watering and skimming of the milk, not only is its nutritive value materially reduced, but the skimmed milk of one day is added to the fresh milk of the next, and the consequence is that the milk is soured, or in other ways rendered entirely unfit for children's food, even before it is delivered to the house. Diarrhœa or summer complaint, convulsions, and death may often follow as the result of such a condition of their exclusive food when they are debilitated by summer heat. It is on this account that this practice is so reprehensible, and it is this which makes rigid inspection necessary, and severe legal punishment upon all offenders justifiable. Of all the adulterations of food so often alluded to, this is one of the most flagrant and injurious to the community at large.

* *Vide* Essays by Drs. Jacobi, Meigs, S. C. Busey and J. Lewis Smith, published by the trustees of the Thomas Wilson Sanitarium of Baltimore.

THE FIRE UNDERWRITERS' REGULATIONS RESPECTING THE USE OF THE ELECTRIC LIGHT.

The electric light has made its way into such general use by reason of its great superiority in quality over every other known system of artificial illumination, that it is rapidly coming to be looked upon as a necessity rather than a luxury, in which latter category it has been customary until lately to class it. Within the past few years, however, much has been accomplished in improving the brilliancy and steadiness of the electric light, in lessening the cost of the several systems, and in perfecting their details of construction and operation; in consequence of which the electric method of illumination to-day, in one form or another, has been very extensively adopted both here and in Europe for the lighting of the streets and avenues of cities, public buildings, mills, factories, stores and the like.

But, though the superiority of the electric light in point of purity over other sources of artificial illumination is incontestible, and though the practical objection of greater cost urged against it has been largely overcome by reason of the improvements above referred to, the fact, which the occurrence of serious accidents has made very apparent, that its use was attended with danger, has given rise to a feeling of general uneasiness and distrust. The fact, which speedily came to light, that the experts of the electric lighting companies, electricians, and others claiming to be familiar with the subject, differed among themselves as to the magnitude of these dangers and the proper precautions to be taken to avoid them, was a discovery calculated rather to increase than to allay public disquietude.

The importance of the subject was such that several prominent scientific and technical organizations, among which may be named the Franklin Institute, were induced to investigate it. These investigations have contributed greatly to a proper understanding of the subject. The report of the special committee of the Institute, which examined the subject, was published in the December number of the JOURNAL for 1881, has been widely read and commented on as an admirable and authoritative statement of the sources of danger in electric lighting, and as a guide in the adoption of preventive measures to provide against them.

The New York Board of Fire Underwriters has likewise taken a strong interest in the question, and through a special committee, appointed for the purpose, they have adopted a set of regulations to govern the introduction and use of electric lights. From the nature of this organization it was to be expected that they would consider the subject from a strictly business standpoint, as their interest in it is based on purely monetary considerations. An examination of the regulations adopted as a standard by the Board confirms this view. They enter into the most elaborate details respecting the precautions to be taken to guard against danger, including therein the questions of the capacity of conductors, the proper methods of insulation, the protection of the lights, etc. In this respect the regulations established by the New York Board of Fire Underwriters will be found useful in connection with the report of the Committee of the Franklin Institute above alluded to. The regulations of the Underwriters, embracing the latest revisions as adopted at a meeting held January 12, 1882, are as follows: W.

Capacity of Conductors.

For Arc Lights—The conductor must have a weight per running foot at least equal to that of the wire (or parallel group of wires) constituting the main circuit of the magnetic regulator of the electric lamps, or of the armature of the machine employed, whichever of these is the largest.

For Incandescent Lights.—Wherever a connection is made between a larger and a smaller conductor at the entrance to or within a building, some approved automatic device must be introduced in the circuit of the smaller conductor, whereby it shall be interrupted whenever the current passing through it is in excess of its safe carrying capacity.

The safe carrying capacity of a wire is that current which it will convey without becoming painfully warm when grasped in the closed hand.

Insulation.

All wires, machines and lamps to be so mounted and secured as to insure complete and continuous insulation, with the exception of those parts (such as portions of the lamps or machines for example) where insulation is impossible, and in this case accidental contact with exterior objects must be prevented by appropriate screens or the like.

In no case must "ground circuits" be employed, or any portion of

the system be allowed to come into conducting connection with the earth through water or gas pipes or otherwise.

Exposed wires must be covered with at least two coatings, one of insulating material next the wire, of a thickness and material approved by the Board, and another outside of this, of a material calculated to protect the former from abrasion or other mechanical injury.

Where there is a possible exposure to water the first or second coating must be impervious to that fluid.

Wherever electricity is carried into a building by conductors from an exterior source a "cut out" must be provided at a point as near as possible to the entrance to such building.

The outgoing and returning wires for Arc Lights should enter and leave each building at points at least one foot from each other.

The wires passing through the exterior walls of a building should be firmly incased in substantial tubes of non-conducting material, not liable to absorb moisture, and placed in such a manner as to prevent rain water from entering the building along the wire.

In running along walls and the like wires should be rigidly attached to the same by non-conducting fastenings (the wires themselves being well insulated) and should not be hung from projecting insulators in loose loops.

All wires should be placed at a distance of eight inches for Arc Lights and two and one-half inches for Incandescent Lights from each other, and wherever they approach any other wire or conducting body capable of furnishing another circuit or ground connection they must be rigidly secured and separated from the same by some continuous solid non-conductor, such as dry wood, of at least one-half inch in thickness.

Wherever wires are carried through walls, floors or partitions in buildings, they must be surrounded by a special insulating tube of substantial material.

All joints in wires must be made in such a manner as to secure a perfect and durable contact. Continuous wires (without joints) to be used as far as possible.

Globes.

Arc Lights must be protected by glass globes, enclosed at the bottom to prevent the fall of ignited particles, and where inflammable materials are present below the lamps, a wire netting must be added

to keep the parts of the globe in place in case of its fracture during use.

All broken and cracked globes to be at once replaced by perfect globes.

In show windows and other places where inflammable materials are near the lights, spark arresters shall be placed at the top of the globes.

Automatic Shunt.

Wherever a current of such high electro-motive force is employed that if concentrated on one lamp of the series it would produce an arc capable of destroying or fusing parts of such lamp, an automatic switch must be introduced in each lamp by which it will be thrown out of circuit before the arc approaches any such dangerous extent.

Companies furnishing electricity from central stations must enter into an agreement with the New York Board of Fire Underwriters, binding themselves to test their lines for ground connections at least *once* every day (and preferable three times per day), and to report the result of such tests to the Board weekly.

Means by which those in charge of the dynamo-electric machines will be warned of any excessive flow of current, or means whereby the same will be automatically checked, must in all cases be provided.

ON THE FILTRATION OF WATER FOR INDUSTRIAL PURPOSES.

By P. Barnes, Springfield, Illinois.

Read at the Meeting of the American Institute of Mining Engineers, May, 1881.

The complete and accurate filtration of water (if the word accurate may be thus used) for the feeding of boilers, and for many similar industrial purposes, although somewhat practiced both at home and abroad, has been by no means common. Even if the exact line cannot be defined at which filtration begins to be called for, and will be found profitable, it is certain that in a large number of cases it may be employed with real advantage in the economy of fuel, and also in the greater durability of the boiler or other form of apparatus in connection with which the water may be used. It may be carried on without any attendant disadvantage of costly apparatus, or of

complex fixtures of any kind, which are liable to get out of repair, perhaps at the time, of all others, when their service is most urgently needed.

No special form of apparatus need be mentioned in this paper, nor need there be any reference to other kinds or types of fixtures than the time-honored device of an open sand-filled tank or basin. A brief discussion of these familiar details may serve to set forth the principles involved, and the entire practicability of applying them to the water-supply of nearly all kinds of industrial work. The general character of this discussion is the more desirable because the waters of different localities vary so widely, and so also do the materials which, being found near at hand, can alone be used profitably in the filtering apparatus.

It is too often supposed that a filter of any kind is, and must necessarily be, only a hopeless annoyance and perplexity to the workmen who have charge of it; but this comes chiefly from using, or attempting to use, a filter far too small for the work, or else from some error in arrangement that ought to be discovered and corrected. Sometimes the effort is made to combine the work of filtration with that of heating the water, if it be used for boilers, or possibly with the storage of the water in some tank of trifling capacity. In many cases the filter is set in some inclosed space, as an engine or boiler-room, where the interruption of cleaning becomes a genuine annoyance to all concerned.

If a simple mechanical sifting alone be attempted, and in most cases this is all that can be brought within the limit of admissible cost, then the problem becomes really a very elementary one, and need not involve any more than the plainest forms of apparatus, and the simplest kind of manipulation for the securing of useful and very perfect results. These plain and even rude appliances are in fact the ones which alone can endure the inevitable rough handling and all the usual exigencies of this class of work.

This discussion should include:

1. A description of the basin, or inclosure, for holding the filtering medium, and, if needful, for the storage of the water after the filtration.

2. A note of the method of putting in the materials used for the filter-bed, as adapted to the wide variety from which selection may have to be made, and also to the ordinary character of the water to be treated.

3. An explanation of the simple method of working under ordinary circumstances.

4. A description of the method to be employed in cleaning the filter, this being almost the sole working cost of the operation, for the first cost of construction may be kept within so moderate a limit that the interest charge upon it will be trifling.

1. The filter-basin or tank should be divided at least into two parts, so that one may be at all times ready for service. If the water is likely sometimes to be heavily charged with mud, a larger number of compartments become needful, for the time needed for cleaning is thus increased, and it is then all the more desirable that the apparatus in which the water is to be used shall be always definitely protected from injury by the mud brought in from the source of supply. These compartments should be of ample size, for the filtering process to be perfect must be carried on slowly. The mechanical sifting out of the fine impurities can only be done by passing the water through a fine-grained or dense medium, and hence the movement of the water through this medium must necessarily be slow. If space can be found, very large basins are desirable, although useful results are obtained in tanks of quite limited size. The outline may suit the space which can be devoted to the basin or tank, being either rectangular or circular as may be needful.

The choice of location for the filter-bed may be made to suit the exigencies of any given case. The basins may be put at the source of supply, perhaps at a distance from the works, the clean water alone being brought through the pipes. On some rivers the material of the bank itself is found to be an admirable filtering medium, so that the cutting or sinking of a plain trench in this material fills the whole requirement. Some filter "galleries," on an extended scale, have been thus made with excellent results. In some cases wells have been sunk by the side of a canal, and from them very pure water has been drawn in ample quantity, which, if taken direct from the muddy canal, would have been subject to a water tax, as well as wholly unfit for the required purpose.

If an open basin be employed, a screen should be so placed as to intercept leaves and similar material, so that they may not be widely scattered and more troublesome to remove. The inlet-pipe should be led in above the usual water-level, so that the amount, and character, as to cleanliness, of the supply may be constantly observed. The outlet

is necessarily led away at the bottom of the tank, and it should have, at the nearest practicable point to the filter, an open discharge, from one pipe into another or into a storage reservoir, so that the purity and the amount of flow may be approximately noted at a glance. The volume of water passing the filter will obviously diminish as the sand surface becomes saturated or filled with mud or silt, and thus, by the flow from an open outlet, the comparative condition of the filter may at once be noted.

2. The material and method of filling must be suited to the water which is passing. One grade of fineness of the surface may be quite sufficient at one season of the year and doubtful or imperfect at another. At the bottom of the basin a layer of tiles, or coarsely broken rock, should be laid, so that an ample and uniform outlet may be had for the water from all parts of the surface area. This tile bottom may serve also a useful purpose in the storage-room, which it furnishes for the clean water.

For the next layer coarsely broken brick, ore, slag, or coke should be used, or, indeed, any material which will not become softened by soaking in the water, and which is of a rather rough or angular texture in its fracture. The next layers may be of the same material more finely crushed, so that at length, at the upper surface, the whole shall be nearly or quite like a fine sand, such as will pass a forty or sixty mesh screen. This method of filling affords in the best possible way the opportunity of correcting any imperfect working, for, by changing from one filter-bed to the alternate, the first may be repacked, or a finer material may be put on as needed, until the required result is reached.

At any iron works one of the best of all materials is usually to be found, viz., hard coke, which, when crushed fine, resembles very closely the animal charcoal so universally employed for the finest filtering, either for household service or for the higher class of manufacturing. In few words, almost anything can be made to serve as filtering material which can be crushed fine enough to act as a mechanical barrier to the sediment or mud borne by the water, and there are very few works or regions in which some kind of rock cannot be obtained.

3. In the working of the filter, the uniform downward soaking away of the water alone needs to be provided for. For this purpose the water should be as uniformly distributed as possible, and should

be led on to the filter very quietly. To prevent any disturbance of the fine sand surface, a quantity of coarser rock or sand should be spread to break the fall or flow of the entering water, or a simple timber or plank apron may be laid. This method of filtration is obviously suited to the cleansing of any quantity of water, whether small or large, up to the maximum capacity of the filter. The smallest quantity is as perfectly dealt with as the largest, and the whole apparatus need suffer no material injury from any probable standing for a time unused.

In some climates an open-basin filter would be subject to freezing, and thus to a complete stopping. As soon, however, as the area or number of basins required for any given establishment has been determined, a simple shed or inclosing roof can be erected at no great cost, which, with the constant flow of the water, will be found ample to prevent obstruction from freezing. In extreme cases the tanks or basins must be fully inclosed in frost-proof casings, or placed inside of some permanent building which shall afford the needful protection.

No method of dealing with the waste water from a manufacturing establishment is so effective as filtration, so far as freeing it from impurities held in suspension is concerned. When elements held in solution must be removed or neutralized, the problem becomes a difficult one, and its solution, in the large majority of cases, quite passes the limit of admissible cost.

4. The gradual diminution of the outward flow from the filter-bed, at the open discharge pipe referred to, gives all needed warning of the choking or filling up of the surface of the sand stratum at the top. When this has reached the fixed limit, the flow of water is turned into one of the duplicate basins, and the first is suffered to become empty and to dry away for cleaning. As a rule, the mud and other obstructing sediment will not be found to penetrate deeply, and hence the removal, by scraping or shoveling, of a thin layer from the surface, of from one to three inches, will be found to restore quite fully the flow of water when it is again turned through the filter. Care must be taken in this shoveling or scraping that none of the silt material is rammed or "puddled" into the crevices of the sand which remains, for few things of its kind are more impervious to still water than a stratum of "puddled" clay or similar material. If time enough be taken to let the water soak away quite completely from the filling, then the saturated surface can be very readily shoveled off and

removed. More of the surface material can then be spread, or the water turned on at once, in case the top layer was made thick enough to permit several cleansings without removal or replenishing. The sand may be washed and returned if it be at all in scanty supply; but if crushed coke be used, its rough surfaces will eventually become so charged or coated with mud as to render it unfit for use.

It has been remarked that the cost of this cleaning is really the sole working expense attending the use of this class of filtering apparatus, and this cost need not be great, or indeed more than quite trifling. The filter must be of the primitive type thus described in order that the common labor, which alone can be charged with the detail of such things, shall make no mistake in the refilling or the cleaning required.

An important though indirect advantage attending the use of a filter, which has no connection with the work of heating the water treated in it, is that the laying off for cleaning may be done at any time, provided only that a separate compartment is so arranged that the flow may be turned through it without any delay. It is obvious enough that duplicate filter-heaters may be provided, but as a rule they are not, and hence the needed cleaning of the filter compartment must be done when the heater can be spared or is idle, as on a Sunday. This necessity is liable to lead to the running of the filter longer than it should be run, and to a general haste and imperfect cleaning when finally it is attempted. This ends at length, or is very likely to, in an imperfect working of the whole apparatus, and a complete abandonment of the attempt to filter the water at all. If, on the other hand, ample filtering appliances are provided, of the elementary type described, then the barrier thus erected for the protection of the higher classes of apparatus, from sand and débris of all kinds, is rendered very complete and permanent.

Sometimes, too, an unexpected deluge of mud is brought in through the water-supply, which, in a very short time, and almost wholly without notice, fills up solid the pipes, pumps, and heaters, and even finds its way into tuyere pipes and into boilers in hurtful quantities. Against such damage as this no guard can be maintained so effective as that of an open filter of ample area and fitted with these plain attachments. If the water needed for boilers is at all charged with oily matter, a good sand filter may be relied upon to remove a large

part of this hurtful element, which, in many instances, has led to the formation in the boiler of a flocculent deposit upon the more highly heated plates, and to their serious injury by its non-conducting power.

Careful attention has been given to this subject by railroad managers for the protection of their locomotives, but, as the quantity consumed in this service is comparatively small, an important part of the purification of the water may be effected by giving it time to settle in a tank. There still remains, however, even after the matter mechanically suspended has been wholly removed, the frequent presence of salts of lime held in solution, and the incrustations due to these are often exceedingly troublesome to deal with. They are such, too, as cannot be eliminated except by heating, and then only in part; but these methods of purification at best are costly, and so quite apart from the purpose of the present paper.

In the first study of a location for a large works, the quantity of water is usually the first question to be considered, while the quality is held as secondary. This may be the more safely permitted if care be taken, in the outfit of the works, to provide the filtering fixtures needed to restore the quality of the water, if doubtful or bad, to a normal and reasonable standard. In any case, the cost of this part of the general apparatus may very justly be taken as an investment for the insurance of the more costly parts of the machinery against one of the causes of injury, from which delay and damage may result. In all the strictly modern works improved appliances are to be found in many of the departments, and improved methods of working are continually sought for and adopted. The use of filtered water, when it can be had at so trifling and quite nominal a cost, is one of the steps in advance in the management of the great masses of steam and other machinery of the present day, and it is worthy of a more careful consideration and more frequent adoption than it has received. With the tendency to constant advance in steam pressures, in temperatures in and around furnace pipes and fixtures, and in the crowding and driving of hydraulic machinery in general, there is need of the use of the very best water-supply that can be had, for the best, whether from natural or artificial sources, is in no way too good for the intense service required.

THE SUGAR BEET INDUSTRY.

By Lewis S. Ware and Robert Grimshaw.

A Paper presented at National Tariff Convention, New York, Nov. 30, 1881.

The futures of nations and inventions are difficult to predict, both being controlled by unknown causes. Who, during the prosperous days of the Byzantine or the Roman empire, would have thought that a few hundred years would have swept it almost totally out of existence? Who, again, could have predicted, during the reign of George III, when this important English colony became independent, that it would later on be the leading nation of the world? What would prehistoric peoples have thought of the possibility of our recent scientific discoveries? In the same line of argument—what have these coming years in store for us? Is a foreign blockade of our eastern coast possible, or are Southern or Western difficulties near at hand? We cannot foresee. Whatever occurs, the commodity in greatest demand should be the first thought of. In the present condition of our commerce, sugar is the greatest imported commodity, and to that so-called luxury we should give our first thoughts. In the South the total sugar made in 1880 was about 200,000,000 pounds, while our total consumption was about 2,000,000,000 pounds; thus in round numbers, we rely upon other countries for nine-tenths of all the sugar we consume, at a present annual outlay of nearly $100,000,000. Whatever occurs, the Southern production is ample for Southern requirements. By present treaties with the Sandwich Islands, their Pacific sugars enter our ports free of duty, thus practically rendering the Western markets independent of the South, while under the present conditions, the Northeastern States have nothing upon which to rely in an emergency. Is not Northern sugar production desirable? Napoleon I foresaw the importance of protecting France, from a sugar point of view. His method, said the great Thiers, "thrice saved the country from ruin." We propose that America follow it, ignoring the unknown future and examining the present conditions of our sugar-growing interests. We notice that in our ninth decade, 28 pounds of sugar per capita per annum were consumed, while, from the present appearance, by the end of the eleventh decade it will be over 50 pounds

(this is 10 pounds less per capita than is consumed to-day in Great Britain). Our reasons for supposing that it will reach that figure are, that statistics prove that annual sugar consumption per capita increases with population and material wealth. In our tenth decade, it was nearly 40 pounds per head, and if our population should increase at the present ratio, there will be in 1890, 60,000,000 people consuming perhaps 3,000,000,000 pounds of sugar per year, which would possibly be worth, at 7 cents per pound, $210,000,000. If our production at that time is only one-fifth of the consumption, or three times the present production, barring unforeseen circumstances, it would be only 600,000,000 pounds; leaving 2,400,000,000 pounds to be imported. This would be worth, at 7 cents per pound, $168,000,000, sufficient to give yearly employment, at two dollars per diem, to 300,000 men; giving our own population the benefit of that home circulation of bullion. Such are the possibilities of the beet sugar industry ten years hence. If we examine into the present consumption, importation and exportation of sugar, we find that we consume 1,601,200,417 pounds of foreign origin, and only 198,945,420 pounds of domestic production, representing a total of 1,800,145,837, say 38 pounds per capita. In 1880 we imported 1,829,302,684 pounds, and exported 10,498,202; the difference between imports and exports being 1,118,804,482 pounds, of a total value, including foreign customs, of $118,749,743. The home production as compared with our population is considerably less than it was before the war; for then, with a population of 30,000,000, it was 302,299,105 pounds, or 10 pounds per capita; while in 1880, with a population of 50,000,000 it is but 264,000,000 of pounds, or 5·2 pounds per capita. This may, no doubt, seem paradoxical, but is true. The levees, which before the war protected the Louisiana plantations from the overflow of the Mississippi river, have in large part been destroyed. They could not be rebuilt for millions—perhaps hundreds of millions—of dollars. If we examine the sugar production of other Southern States than Louisiana, we will find that in South Carolina there has been an immense falling off in ten years, while in Mississippi it is now but nine-tenths of what it was twenty years ago. In 1860 the production in Louisiana was one-third of the total consumption in the United States; to-day it is much less. Yet our gross consumption of foreign sugars has more than doubled in twenty years, being in 1860, 660,777,673, and in 1880, 1,601,200,417 pounds. The consumption of home sugars has consequently decreased

nearly 1,000,000,000 of pounds. Such are the extraordinary fluctuations of our most important commodity. Is it not imperative that we look before it is too late to some other source than the cane for our sugar supply? Many of our sugar refiners and brokers, whose principal trade is carried on with Cuba, etc., offer considerable objection to home sugar production, but we fail to see where their interests would be in any way impaired; especially as within a few years slavery is to be abolished in Cuba. Are we not especially favored for home sugar production? Will the commerce existing between the United States and Cuba be as great after slavery has been abolished as to-day? If those foreign sugar-producing countries should no longer exist, we are convinced they would in no way diminish the interests of our refiners, who would then be interested in our home sugar production, which they are not, to any extent, to-day, being in many cases interested in sugar plantations outside of their mother country. Yet their direct refining business is practically less to-day than it was prior to the introduction of improved methods upon these sugar plantations.

The question of transportation from foreign shores and the placing of sugar upon the market at the most desirable time is an item that should not be overlooked when this grand sugar question is discussed. With the sugar beet, for example, refined sugar might be produced from the root and placed upon the market at least one month earlier than either foreign or domestic cane sugar, thereby realizing the greatest profit at the season when sugars sell highest. The importance of having a minimum freight upon a merchandise is indisputable; yet in the Southern States the sugar cane can never fulfill this condition, and climatic conditions do not permit the maturing of the sugar cane in the South until at least one month later than the sugar beet in the North. In European countries, where these difficulties were realized, they sought some other plant than cane for supplying their home sugar. Many were resorted to in 1800; sorghum and maize were tried, but attempts at their utilization were soon abandoned. Yet, completely ignoring the experience of those older nations, we have, in consequence, spent hundreds of thousands of dollars in theorizing and in experiments with sorghum and corn stalks, yielding absolutely nothing. A recent pamphlet by Lewis S. Ware, "On the Various Sources of Sugar,"* reviewed the five thousand experiments made by

* Published by Henry Carey Baird & Co., 810 Walnut street, Philadelphia. 8vo.

our Agricultural Department at Washington, and showed that very little over three per cent. of sugar could be extracted from sorghum and none from corn stalks. Is not this contemptible yield sufficient to condemn these alleged sugar-yielding plants? In all cases, the impurities in the sub-varieties of sugar cane prevent the crystallization of their saccharine juices. Hence the impossibility of extracting as sugar what sucrose they might possibly contain. Even if these insuperable difficulties were not to be contended with, we should condemn these plants, from which the cane sugar disappears within fifteen days after cutting rendering storage impossible, and economical manufacture impracticable. Again, the entire subject of sorghum and corn stalk sugar is yet in its laboratory stage, doing little toward solving the grand problem of manufacturing the sugar we consume. If we consider the maple tree, the idea of its utilization on a large scale is ridiculous. The same may be said of all other sources, the sweet potato, etc., from which, outside of the laboratory, nothing has been or can be obtained. But the sugar beet furnishes to-day nearly one-half the sugar of the civilized world. Many assert that beet sugar making in this country is impossible, basing their assertion on past failures, without looking to their causes. Efforts were made to introduce beet sugar making into the United States as early as 1829, a factory being established in Livingston county, and subsequently removed to Stevenson county, Ill. In 1869 the German Beet Sugar Company was organized at Chatsworth, Ill. In 1866 Fond du Lac, Wis., had a factory, which was moved to Alvarado, Cal. In 1870 the Santa Clara Valley establishment, California, was organized, but this was moved to Black Hawk, Wis. In 1878 the Portland, Me., factory was started, but it has been divided up—south, east and west. In 1879 the factory at Franklin, Mass., was established, and we now hear talk of moving it to Schenectady, N. Y.

Throwing aside our possible personal prejudices in favor of the beet-sugar industry, we appeal to the American people for fair judgment on these failures. It is rational to suppose that if these so-called beet-sugar factories, organized, in nine cases out of ten, by those not having the slightest idea of the requirements thereof, and failing in consequence, had been started in Europe by the same persons, and with the same limited capital, they would there have met with the same results. We cannot here in a few lines recall the whys and wherefores,

but will only say that all future establishments of this kind started with a capital of less than $200,000, or far from the centre of demand, or where water and fuel are not cheap and abundant, or where the technical manager does not understand in every detail the workings of the establishment, will inevitably fail. On the other hand, if correct principles be followed, success is almost guaranteed in advance. We have only to cite two recently organized existing factories, one representing Western enterprise and the other Eastern, which are wonderfully deserving for their perseverance, and which are manufacturing excellent sugar. One of these (the Alvarado factory) is dividend paying.* Its sugar is a staple article on the San Francisco market, where it successfully competes with that from the Sandwich Islands. The Delaware Beet Sugar Company, near Wilmington, expects to manufacture this year at least 150,000 pounds of sugar. The Alvarado Company has excellent beets; its sugar product for 1881–1882 is yet unknown, but will doubtless greatly exceed that of the past. Now, here we have two sensibly organized factories that meet with success, while the illy-placed, under-capitaled and ignorantly managed establishments have passed out of existence. What would be thought of moving a large Brooklyn sugar refinery two or three hundred miles from where it is now standing? It is not equally absurd to transport a beet-sugar factory? Yet all these difficulties are not greater than existed in Europe during the early stage of beet-sugar making. As far back as 1747, the great Prussian chemist, Margraff, called attention to the sugar existing in the beet, and the possibility and importance of its extraction. In 1830 some few sugar factories were working. In 1846, nearly a century from the date of its discovery, 100 beet sugar factories were started in the face of opposition of all kinds. From that time until 1860 the questions of home taxation, foreign colonial interests, etc., threw great obstacles in the way. In other words, it took over thirty years in France to establish this beet sugar industry on a proper foundation. But to-day what is the result? There are in Germany, Austria, France, Belgium, Holland and Russia no less

* We have seen, since the above was in type, a letter from Mr. E. H. Dyer, Superintendent of the Alvarado Sugar Refinery here referred to, addressed to Mr. L. S. Ware, in which he communicates the gratifying information that as the result of their year's work, the establishment has earned 20 per cent upon its capital stock, or 30 per cent. upon the capital actually invested. W.

than 1,500 beet-sugar factories, with an annual production of nearly 3,000,000,000 pounds, and there is no possible reason why we should not avail ourselves at once of the results attained by those older countries in a long series of experiments. If we are to consider as impossible the establishment of the sugar beet industries in the United States, we can no longer consider ourselves the leading—or even a leading—country of the civilized world; and with all our advantages of cheap land, favorable climate, ample capital, intelligent labor, and time-saving, labor-saving and money-saving devices—we had better take a back seat in the grand classification of nations.

But this problem will be commercially solved, beyond all question, within the next few years. The advantages to be derived from the manufacture of all the sugar that we consume are of an importance that can hardly be realized at first thought. It would render our country industrially and politically independent as regards the most important of commodities. It would introduce a new system of farming, much needed in the New England States. It would place milk, butter, cheese, lard, pork and beef upon our market in still greater abundance, to the advantage of our laboring classes and of our export trade To supply the United States with 2,000,000,000 pounds of sugar would occupy 1,000,000 acres of land per year, and, making allowance for the desirable rotation of crops, it would be indirectly the means of working at least 4,000,000 acres. The yield of beets would be about 20,000,000,000 pounds. Their manufacture into sugar would consume over 4,000,000,000 pounds of coal; we would have 6,000,000,000 pounds of pulp, representing 35,000,000 pounds of meat. Besides the meat, the manure resulting from feeding cattle on the pulp would be 2,800,000,000 pounds. There would be over 1,000,000,000 pounds of molasses, from which could be made over 32,000,000 gallons of alcohol at 96°B. Employment would be given to nearly 300,000 men, women and children. We would thus give a new market for such materials, consumed or resulting, as coal, bone-black, limestone, matches, brushes, leather, plaster, oils, lubricators of various kinds, sulphur, sulphate of iron, salts of ammonia, soda, bisulphite of lime, muriatic acid, wire of all kinds, rivets, bolts, zinc, tin, borax, tar, oils for various purposes, etc. Besides, there would be needed millions of pounds of iron for construction and for various machines in and out of the factory, and hundreds of millions of bricks

for factory buildings. We would give employment to engineers, chemists and many other branches of industry, and largely increase the demand for hundreds of home products. Further, this would gradually increase the yearly freight traffic on railroads, water-ways, etc. The country at large would be benefited under the circumstances. We do not know but that governmental encouragement would be desirable. We could then have the very best machines and the highest talent in the best possible location, all of which could not so well be realized under existing conditions. Individuals having property to sell offer arguments in favor of beet cultivation in their particular localities. Overlooking the most important of all other facts, that of probable sugar exhaustion, what would be the possible sugar result? While these lands might be desirable for the cultivation of grain, they might be disastrous for that of sugar beets.

In conclusion, we would say that no less than three factories will be started in Canada in the present year. These, however, are not Canadian enterprises, but started by foreign capitalists who have sufficient forethought to realize that there is money in sugar beets on this continent, notwithstanding unthinking American arguments as to former failures, which prove nothing against intelligent beet sugar making.

Are we, the people of the United States, to wait for foreign capital to establish among us beet sugar making on an extended scale; or are we to take immediate action, and prove to Europeans that we are capable of taking care of ourselves without their capital by prudently availing ourselves of their past experience, which we have heretofore so frequently overlooked?

We demand, then, that American farmers shall essay the proper cultivation of sugar beets for cattle feeding, and sugar and alcohol making; that American capitalists shall undertake beet sugar and alcohol making under proper auspices, in favorable localities, and with sufficient capital; that state and county premiums be given for the largest and for the richest beet crops, and for the first commercially successful beet sugar factories and beet alcohol distilleries; and that a fostering government give such rebates upon home Northern sugars, and such appropriations for ample researches, experiments and reports as shall enable us within ten years to freight our out-bound ships with sugar from the North, to sweeten the great eastward-bound grain and flour product of the new Northwest.

RECENT IMPROVEMENTS IN THE MECHANIC ARTS.

A novel invention, which has for its object the automatic setting out of the packing rings of a piston-head within the cylinder, has been devised by the Master Mechanic of the Pennsylvania R.R. Co. and will be adopted by that company for use on their locomotives. The improvement consists of a solid piston-head suitably cored out for the reception of the packing rings and their actuating levers, as also for the two adjustable bolts which centre the piston and provide the bearings against which the weight of the piston exerts itself to set the packing out automatically. The two operating levers are each fulcrumed in a block resting on the packing rings at the bottom of the piston and extend, one on each side, into the upper circumference of the head, where they rest against other blocks having their bearings on the packing rings and constituting the *resistance* of the levers. The *power* is applied through the two threaded bolts referred to and which work adjustably in screw bearings in the solid head. These bolts are each arranged on an angle of 30°. Thus, it will be seen that the whole weight of the piston rests upon these two bolts which, in turn, bear respectively against their levers, whose fulcrums are in the bottom of the piston and whose resistances or operating ends are in the upper part of the piston, whereby the weight of the same is utilized, through said levers, to bear directly against the upper circumference of the packing rings to expand the same in the upper part of the cylinder.

A recent improvement, tending to increased safety in railroad travel, consists of a frangible tube projecting from the cab of a locomotive and communicating with the brake-pipe of the Eames or Westinghouse system of air-brake apparatus. A switch, drawbridge, etc., have wires or ropes attached to them which lead to semaphore arms arranged at a distant point on each side of the switch or draw. These semaphore arms are so arranged that when a switch is misplaced the arms will lie across the path of the frangible tube on the locomotive, whereby said tube will be shattered and the brakes instantaneously applied. In the Eames improved system, a constant vacuum is maintained in the brake-pipes, the brakes being set by the destruction of the vacuum, which has the effect of opening up the vacuum power of auxiliary reservoirs located under each car; thus, it will be observed that the breaking of

this frangible tube will destroy the vacuum in the brake-pipe. In like manner, in the Westinghouse system, a continuous pressure of air is kept up in the main brake-pipe, the reduction of which opens up secondary reservoirs under each car, which operates the pistons of the brake apparatus.

A late invention provides means for extinguishing fires in the stoves of passenger cars should they, by any accident, upset. For this purpose an elongated water-reservoir is suspended along the side of the car. Cords, attached to the stove and to valves which normally close outlets in the reservoir, serve to operate said valves when the stove is upset, and allow the water, through a perforated distributor, to flow into the fire.

A new staple of manufacture consists of the fibre of the stalks of cotton plants. The stalk is disintegrated and the fibre separated from the rest of the stalk, preserved and prepared according to the following method: First separating the fibre from the stalk by passing through rollers or by retting, then drying, then scutching or breaking, and then carding or hackling the same, thus producing a staple of the fibre alone. It is proposed to manufacture from this staple woven fabrics by spinning it and converting it into twine, cordage and yarns, wadding, packing, calking and paper. F. B. Brock.

Washington, D. C.

CORRESPONDENCE.

The following correspondence, received by the Secretary for presentation to the Institute at the stated meeting in March, has been deemed of sufficient interest to warrant its publication:

THE HUDSON RIVER TUNNEL.

Secretary of the Franklin Institute:

Dear Sir—In forwarding you the following memoranda of progress and experiences of the past year, I would say by way of introduction that there is but little that is curious or novel in it that has not also been the experience of similar undertakings, or rather so much of others as resemble it from any aspect, viz., that of working under a pressure greater than normal atmospheric pressure; in this a record of what occurs here would be much the same as numerous well-told

experiences of sinking pneumatic caissons show; and of tunneling, generally, surely enough has already been said, while of a combination of these processes there has but little come under our observation so far, and but little can we now add.

It is assumed that you are sufficiently well acquainted with the general features and scope of the enterprise, and only a statement of its magnitude is here offered, viz.:

Two tunnels, both as to grade and alignment parallel, as near as may be; each to accommodate a single line of rails; east and west bound traffic.

Length of tunnels from shaft 83 feet, inboard on New Jersey shore to caisson 90, inside of bulkhead wall on New York side of the river 5500 feet.

Approaches at either end about 4000 feet each. Greatest depth of water overhead at mean tide 60 feet.

Operations were begun in 1874, although but very little was accomplished, owing to litigation, until August, 1879, since which time the work has been carried on continuously.

The inauguration consisted in sinking an open shaft, 30 feet internal diameter, with walls 4 feet in thickness, to a depth of 60 feet; at a depth of 40 feet an angular opening was made in the side of the shaft, and one end of an air-lock inserted, and the excavation began.

Up to March 1st, 1881, some 260 linear feet had been completed in the north and 250 in the south tunnel, when it became apparent that too much duty was put upon the compressors to maintain the required pressure, owing to numerous air-leaks, of greater or less dimensions, and it was decided to erect in each tunnel a bulkhead of somewhat permanent character, move the air-lock forward to this bulkhead, thus reducing the size of the air-chamber and consequently the volume of air supply necessary to keep up the desired pressure.

But it was deemed best not to let off the pressure at the headings while this was done, which involved the construction of air-locks in pieces that could be passed through the lock in the side of the shaft, the doors of which were 3 feet by 4 feet.

This, it is believed, happened to be the first instance where an air-lock was made in so many parts, and erected under pressure. The specification is enclosed, and it need only be stated here, what is obvious on inspection, that they have proved entirely satisfactory.

In the meantime the work was pushed forward until 450 feet in

each tunnel had been completed, when the bulkheads mentioned were built 420 feet from the shaft, the air-locks set up in them, as shown on sketch, and in place of one large air chamber (in all about 900 feet long), it was possible to change to two, each only 30 feet in length.

Previous to this change there were three air chambers, of which I send you a sketch, which requires no further explanation, except it may be stated that the pressure west of the bulkheads was kept at 15 to 18 pounds, in the north heading 18 to 20, and in the south heading 22 to 24 pounds per square inch above atmospheric pressure. This, however, required too much care and attention, and a decision was finally reached to allow the pressure west of bulkhead to fall to normal condition, and on August 11th the men were brought out of the heading, and the air allowed to escape from as many openings as could be made through steam, air and water pipes leading to or from this portion of the work. About an hour was required for the pressure to run down to 1 pound per square inch as indicated on the mercury column in engine room; no further decrease could be gained, owing to leakage from the other chambers, and the door of air-lock was forced open with a hydraulic jack, and Mr. D. C. Haskin, the originator of the tunnel, entered without the process of "locking" through.

Shortly after, however, the door of the old lock was closed. As the bulkhead in the north tunnel had been but recently built it was thought best not to subject it to a pressure of more than 20 pounds to the square inch, and orders were given to let the pressure in the headings run down to that. When the pressure was let off from the main part of the tunnel there was far more air leakage through and around the bulkhead walls than was anticipated, so that the pressure ran still lower, though the compressors were run at as high speed as was consistent with safety. The reduced pressure in the south heading was not sufficient, and the silt moved slowly in some 25 feet.

The bulkhead walls were of brick, four feet in thickness, backed by a solid timber wall of yellow pine, 12 inches by 12 inches, and strongly braced, as shown on sketch. Two locks were set up in each bulkhead, either of which would contain all the men engaged at any one time in the heading, and instructions given to keep one of them at all times open in that direction, in order to secure a retreat for workmen in case of accident resulting in an influx of material at the heading that could not be controlled. This probably increased the

confidence of the men—if, indeed, it were necessary—although subsequent experience seems clearly to prove that no probability exists for this precaution, as the silt moves very slow when entirely relieved of pressure from within the air chamber. Two locks are recommended, however, in similar cases, entirely from an economical point of view, making it possible to pass materials, either of excavation or for construction, through them with so much greater expedition and convenience.

Previous to the construction of the bulkheads the excavation was carried on by mixing the silt with about 25 per cent. of water, and forcing it out with air pressure, as the usual practice; since then, however, until the 1st inst., the excavated silt has been removed by an "Eads sand pump." This gave good results, taking out sometimes as high as 30 per cent. of silt, but in consequence of the great distance there began to be indications that the limit was approached. At this time a "silt pump," designed by Mr. Chas. W. Clift, M.E. of the tunnel, was tried and found to be very satisfactory until the present time, and, being a simple, straightforward contrivance, was much liked.

The experiment is now being made of removing the silt from the heading in its natural condition, and as yet it is impossible to state as to the relative economy. The hydraulic method of excavation was rapid, but considerable inconvenience was experienced from the waste water; on the other hand, in sending the silt out dry it requires more handling, but leaves the heading in much better condition for putting masonry in.

Of the temporary entrance from the shaft to the tunnels there yet remained a short wedge-shaped section to be constructed, and which had been under consideration during the whole year, 1881, and of course various methods had been proposed, freely discussed and criticised, and rejected. The writer, fortunately, was the author of the last plan suggested, which was adopted, and which consisted in simply closing the doors of the old air-lock, increasing the pressure within again, and drifting westerly from the chamber joining the tunnels to the shaft.

Thus two short sections of tunnel were built without noteworthy incident, unless perhaps mention may be made of the relief afforded by pumping from the stand-pipe in the shaft some 25 feet distant,

which appeared to reduce the pressure, and at all events the volume of water when the excavation was going on.

It may be better, by way of explanation, to state that it was necessary to remove nearly all the overlying silt at that point and expose the water-bearing strata of sand, and also that during the three weeks that the above work was going on, a horse was kept continuously under a pressure averaging 10 pounds per square inch above the atmosphere. A loss of horse-power was calculated but, like many other well calculated plans, they went astray (for the horse still lives).

Now of the processes in vogue at the heading, the manner of advancing or driving the pilot forward may first be considered.

The pilot is 6 feet 6 inches in diameter, made up of 10 plates in each ring about 2 feet wide by 3 feet long, with angle bars 4 inches by 4 inches by $\frac{1}{2}$ inch on the inside for bolting the plates and successive rings together.

The operations are first to make an open cut in the heading of sufficient size to admit one plate, which is supported by bracing from the bottom of the cut, another cut is then made at one side and a second plate put up and bolted to the first, then a third plate is put up on the other side of the first, and other plates are added on alternate sides, working downward until the ring is completed.

Then a second ring is put up in advance by a like procedure, it is also securely bolted to the first ring; work in driving the pilot forward is kept up until a distance of about 40 feet beyond the heading is reached, when the work is suspended to allow the finished tunnel to overtake the pilot, when work on both pilot and tunnel will be carried on simultaneously.

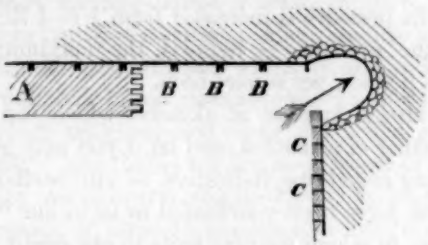
The back end of pilot usually extends 10 feet or more into the completed tunnel from which it is firmly held by braces. The forward end being well advanced into firm silt, it is practically immovable and, together with its advantage as an exploring agent, it forms a kind of bridge or brace against which radial braces are set to hold the iron shell in place while the masonry is being built.

After which uses the rear rings are taken down, carried forward and bolted on at the front end to do duty over again.

The iron shell of tunnel is put up in much the same manner, except that these plates remain as a part of the structure.

There have been, however, several occasions when the following novel and somewhat difficult undertaking has been successfully per-

formed, viz., that of making an opening of the required dimensions to insert a plate without excavating any material; this would occur when soft silt was encountered or, as we call it, when from any cause the heading became "demoralized."



The following figure may assist somewhat in making the description clearer, where "*a*" represents the end of finished brickwork, "*b*, *b*" rings of the iron shell, "*c*" a temporary bulkhead of 4 inches by 6 inches timber or sometimes 2 inches plank doubled. But the work must go on, and a hole is cut in the bulkhead large enough to admit a man's hand. Instantly the silt begins to ooze in and the air to escape. But a man stands ready with balls of quite dry silt, brought in for the purpose, from 4 to 6 inches in diameter, which were rapidly plastered into the soft ooze and pressed back; thus the progress of the silt was stayed. Carefully one ball after another was inserted of this puddle and gently pushed backward until a kind of skin or shell was formed of it; these successive additions being pressed together until an air-tight concavity had been made.

Then a gentle onward motion was given and continued till the opening assumed dimensions sufficient to put up the plate, which advanced the heading 2 feet 6 inches by 4 feet of the circumference.

Occasionally the skin of puddle would become impaired and the soft silt force its way past the hand; then the air would escape in considerable volume with a sound peculiarly suggestive and threatening (should be heard to be appreciated), bringing all hands and the liveliest kind of work to repair the breech. Sometimes it could be repaired with one or two more balls of the hard silt, at others bags of sawdust and short pieces of plank and anything that came to hand had to be used. But the excavation would be made and the plate put in place without taking any material from the heading, although 4 hours' work of 12 to 15 men would now and then be required.

Again the pressure of air required for carrying on the work by the

pneumatic process is determined chiefly from day to day by actual observation, although the theoretical pressure due to a column of water of the height or depth of the work is a very close approximation, and this is varied only as the silt becomes soft or dry and flaky. If the former the pressure is increased from $\frac{1}{4}$ to $\frac{1}{2}$ lb. per square inch, if the latter the pressure is reduced, the maximum variation not exceeding three pounds per square inch.

I send you also a number of sketches which you will understand without any further explanation, and trust you may gather from them and the foregoing something indicative of our methods and some of the secrets which have been vouchsafed to us in our "digging" up to the present time, in which we now have to our credit nearly 1400 lineal feet of completed tunnel.

S. H. FINCH.

New York, March 10, 1882.

SPECIFICATION FOR AIR-LOCKS.

Each "lock" to consist of a cylindrical main body.

Inside diameter 6 feet, inside length 15 feet, in 5 rings of 2 plates each. To each plate is riveted an angle bar $\left\{ \begin{matrix} 3\frac{1}{2} \\ 3 \end{matrix} \right.$ inches by 3 inches by $\frac{3}{8}$ inch, the outside periphery same as plate, longitudinal faces of same to lie in the direction of radius of shell, and transverse faces to be perpendicular to axis of cylinder. Rivets $\frac{3}{4}$ inch diameter, 2 inches "pitch," and holes for $\frac{3}{4}$ bolts $2\frac{1}{2}$ inches "pitch." Heads and nuts of bolts to be hexagon.

The ends of shell to be $\frac{1}{2}$ inch thick, in two pieces, each with angle bars riveted to both sides of plate, and provided with doors with true surface, 2 inches wide, running around outside edge of door, and corresponding seat, $\frac{1}{2}$ inch in thickness, riveted to heads of cylinder with countersunk rivets. Doors to be stiffened with 2 "T" irons, 3 by 4 by $\frac{1}{2}$ inch, and provided with hinges, latch and handle as shown.

Stays or straps, 15 inches by $3\frac{1}{2}$ inches by $\frac{5}{8}$ inch, are required on inside of shell placed 12 inches from centre; holes in shell bored to draw $\frac{1}{16}$ inch.

The following pipes are also required, each end to be fitted with packing glands:

1 air supply pipe, 3 inches inside diameter.
6 water and steam pipes, 2 inches inside diameter.
2 equalizing pipes, $1\frac{1}{2}$ inches inside diameter.
1 blow-out pipe, 6 inches inside diameter.

One 8-inch bull's-eye in each door to be inserted. Plate of C No. 1 iron.

Coppering Iron.—For the past ten years M. F. Weil has been testing specimens of cast and wrought iron and steel which have been coated with copper by his methods, without requiring any intermediate deposit or any finishing touches. The homogeneity of the deposits reproduces the most delicate details of ornamentation, so as to give the articles the artistic value of bronze. The cyanides, which are injurious to the health of workmen and which greatly increase the cost of coppering, are replaced in his methods by organic acids or by glycerine, materials which are cheap and which have the advantage of not being decomposed. The baths require no renewal of organic materials, provided they are properly snpplied with oxide of copper. The well-known property of alkaline-organic solutions, of rapidly dissolving oxide of iron without attacking the metallic iron, facilitates the perfect cleansing of the pieces. When the oxide of copper requires renewal, the exact amount which is needed is determined by a very easy test. Various other metals, such as nickel, cobalt, antimony, tin, etc., can be deposited upon iron and other metals by his processes.—*Comptes Rendus.* C.

Improvements in Bleaching.—A medal has been awarded by the Societé Industrielle de Mulhouse to Charles Weber & Co. for bleaching cotton thread upon bobbins and spools without passing through the various customary processes. Their method enables them to reduce the cost from 25 to 40 per cent., according to the fineness of the thread. They are thus able to export their products into various countries where they could never have been sold in a crude state. They use great monolith vats, of a cubic form and with a capacity of six cubic metres (7·848 cubic yards). The spools, carefully packed, are placed in these vats, which are then closed by granite covers hermetically sealed. The heavy covers are easily managed by means of overhead traveling cranes. The spools are completely bleached in these vats, from which they are removed to improved dryers. Pure water being one of the indispensable conditions for their process, they bored a well with which they connected a forcing pump and filters. The pump is so constructed that it can also be employed for extinguishing fires. The washing and bleaching waters are rendered inoffensive by passing into four great cement wells where they deposit their impurities. Many American improvements have been introduced in their machinery.—*Bull. de la Soc. Industr.* C.

Influence of Electric Light upon Plants.—The experiments of the Champs Elysées have shown that elestric light alone is sufficient to maintain life for two months in plants which are accustomed to the light of the open air. Prof. Dèherain rrcommends that investigations should be undertaken to determine by what methods the light may be most advantageously employed in greenhouses. It is especially desirable to inquire whether the incandescent lamps, which give a yellowish light, are not probably richer in radiations that are favorable to vegetation than the violet light of regulators. The solar lamp, in which the light emanates from lime that has been made incandescent by the electric arc, is probably richer in useful rays than the arc itself. —*L'Electricien.* C.

Influence of the Choroid upon Keenness of Vision.—Most physiologists have assigned to the choroid merely the office of absorbing, by its layer of pigment, the luminous rays which have traversed the retina, so that they may not be reflected towards the pupil. They compare the pigment to the black varnish that is used in the interior of optical instruments. M. Fano thinks that its vascular structure is designed for bringing to the retina the greater part of its nutritive elements, and he believes that he has shown, by numerous experiments, an important influence which it exercises upon the sharpness of vision. Patients who are afflicted with an atrophy of the choroid are generally short-sighted. If this defect was owing merely to a peculiar state of the refracting media it could be remedied by suitable glasses. There are many cases which cannot be be helped by artificial means. In every such instance it is probable that careful observation will detect alterations of the choroid membrane.—*Les Mondes.* C.

The New Fountain of Milan.—E. Paladini has published some notes upon the hydraulic works for the use of the Industrial Exposition and of the new fountain of Milan. The total cost of the works was 80,000 lire ($16,000). The daily supply of the fountain costs nine lire ($1.80). The water is thrown to a height of 27 metres (29·528 yards), with an expenditure of 34 litres of water (8·975 gallons) per second. The effect is quite as striking as that of either of the other great fountains of Europe. The Berna fountain consumes 70 litres per second; the Trafalgar Square, 64; the Stoccarda, 62; the Turin, 50; each of the fountains of the Place de la Concorde, 61; each of the Rond Point, 36; that of the Place Belle Court, 40, and that in the Place du-Chateau, Bruxelles, 40.—*Il Politecnico.* C.

Steamer "Phosphor-Bronze."—An English company has built a steamer of phosphor-bronze, to which it has given the name of the metal. The length is 10·5 metres (11·393 yards) and the breadth 1·8 metres (1·969 yards). On its experimental trip it gave a velocity of 12½ miles, which is a rapid speed for a boat of its size. The object of the company in constructing so small a vessel was to test the rigidity of phosphor-bronze, both in plates and angular pieces, before employing it for larger boats. The results are more satisfactory than were anticipated. The cost will not much exceed that of iron or steel, and as the bronze does not corrode, the value of the raw material will be preserved.—*Gaceta Industrial.* C.

Borate of Soda.—M. Widemann finds that if 12,000 kilogrammes (12 tons) of soda are dissolved in 2000 litres (528·37 gallons) of water and the solution is saturated with boric acid or *tinkal* and then boiled, a borate of soda is produced which has five equivalents of water, while ordinary borax contains ten. If borate of soda is calcined and melted in a crucible and then poured upon a plate of glass or very dry stone, it may be pulverized and placed upon a piece of damp linen or unsized paper, when there is a very rapid elevation of temperature to about 80°C. (176°F.). This property may be employed for producing a warm poultice with cold water, without danger of burning or inflaming the skin, or for warming food, etc.—*Chron. Industr.* C.

Last Eruption of Mauna Loa.—The late eruption of this volcano was the greatest that has been observed for fifty years. The lava flowed regularly and without interruption for nearly nine months and a half. A cloud commonly rested over the hot lava, which was doubtless formed, like ordinary clouds, by the ascending heated air, which was loaded with invisible vapors that were condensed by the cold currents of the upper atmosphere. The condensed moisture, in descending, formed a kind of cyclone or water-spout, which was precipitated upon the incandescent lava and reduced again to vapor. As there were commonly many square miles of lava at a red heat, these storms were frequent and gave some faint idea of the disturbances which are continually taking place at the surface of the sun.—*Comptes Rendus.* C.

Hydro-Motors.—The city of Geneva furnishes water for small engines at 5 centimes per cubic metre (1 cent per cubic yard), under a pressure of 4½ atmospheres, thus giving a horse-power for 35 centimes (7 cents) per hour. This is only half the charge that is made for water for domestic purposes. Two kinds of apparatus are used—one acting on the plan of the turbine, the other through pistons which are moved by pressure. The second seems to be generally preferred.—*Soc. des Ing. Civ.* C.

Book Notices.

STEAM HEATING FOR BUILDINGS. By Wm. J. Baldwin. New York: John Wiley & Sons, 1882. Second edition.

To do full justice to this treatise on steam heating, the writer of this notice felt impelled to refer by way of comparison to the most recent *previous* work on steam heating in the English (or any other) language, and took from his book-shelves the bound volume of Essays on the Economy of Fuel—the Effects of Heat and on Heating by steam. Robertson Buchanan, Glasgow, 1810. (Second edition, or enlargement from a pamphlet of 1807.)

It is difficult to appreciate that an entire industry could have had a progress and development of eighty to ninety years and remain without especial description or record, except what is to be found in this forgotten treatise of seventy-two years since. And with this absence of report of progress, it becomes peculiarly interesting to trace the degree of advance in principle or in apparatus which the two books indicate. For the principles involved, a discussion of which forms the first part of Buchanan's book and a portion of Baldwin's work, it is not sure that the older writer has not presented the more thorough and practical considerations, statements and tables, although his authorities are Belidor, Prony, Dalton, De Luc, Boerhave, Watt, Black, Leslie, Rumford and others, while Baldwin has Regnault, Rankine and more modern lights. (By the way, it should have been recognized by Baldwin that Rankine's formulæ were deductions from Regnault's data, sometimes modified to meet Rankine's thermo-dynamic hypotheses.) For the methods Buchanan treats, generally, of a quite dissimilar apparatus—that with cast-iron flange pipes, while Baldwin restricts his

discussions mainly to the practice of wrought iron pipe steam heating as employed for house warming, with a little of extension to other purposes.

The types of steam heating apparatus used in America are peculiarly American, especially the apparatus of small wrought iron tubes, which had its origin at the hands of the late Joseph Nason, between 1840 and 1850. The essential detail lying at the basis of this trade is to be found in the apparently insignificant feature of the taper screw thread, which gave a ready means of making a sure and perfect joint for pipes and *fittings*, which latter Mr. Nason devised and provided in so many forms, that little addition to their number has been made since his original inception. To be sure, the united ingenuity of hundreds of skilled and intelligent workmen has developed some improvements. But it is certain that in all mechanical growths a type becomes established in marked features, so distinctive that the deviations are merely subsidiary, and rarely essential or even important, except as facilities rather than necessaries; in this manner the American system of steam heating has grown from its original root.

As a record of practice at this day this work of Mr. Baldwin's is fairly representative. In some ways it might be extended, for the steam heating apparatus, particularly discussed, is the customary house apparatus, appropriately denominated a *low-pressure gravity circulation;* while larger or more extensive apparatuses are not so fully considered. The articles on boilers, grates and chimneys are much more general. Those on other applications of heat, as drying, cooking, hot water supply, again have incomplete exemplification. Even in the details of construction, where it might have been supposed that a practical work would have been very elaborate, there are some important omissions. Thus the universal box coil is mentioned only by name, not even illustrated or described, although alluded to frequently, while its innumerable modifications have at least the importance in general steam heating, that the changes of the vertical coil, so profusely shown, possess.

The approximate rule for computation of extent of heating surface is stated to be a square foot of heating surface to 100 cubic feet of space, with the addition of 15 to 30 per cent. for exposed or corner rooms, qualified by other considerations of quality of building, etc. Might not a qualification for character of surface be needed? It is probable that vertical surfaces of all kinds would have to be taken as

of less value than horizontal surfaces. Vertical tube coils should be admitted to be less efficient than box coils with equidistant tubes in equal numbers.

Although disarmed from caviling by the first proposition of the title-page and preface, that the work is intended as "hints to steam-fitters," rather than defined instructions, yet it may be fair in the interest of knowledge to remark on some points. The difficulty of controlling the temperature of steam-heated surfaces—steam of 212° and above, by throttling the steam supply to any particular extent of surface, does need mention, and the regulation of extent of surface by division into separate parts should be stated, with perhaps other ways.

As a matter of fact, the only changes in sizes of wrought iron tubes in thirty-three years, are found in the 3½- and 4-inch tubes, which were originated in this country in 1849, one-fourth an inch larger than the English standards, and were made for fourteen years *over-sized*. Any other deviations of "old sizes" are errors of individual steam-fitters.

It should be fully recognized that the *air* difficulty is the most important obstacle to circulation to be encountered, and with this assertion, the methods of expulsion of air from the upright return pipes, systems 1, 2 and 3, of the illustrations, are not easy to comprehend. The usefulness of separating vessels, relieved by metallic air traps, at the *effective* water-line in returns partially filled could be insisted on.

Above all, the dictum that "*A building heated altogether by indirect radiation cannot be other than sufficiently ventilated*" will scarcely command unqualified assent. Systematic ventilation will remain a necessity, whether the heating is incident to a limited supply of air or not.

Whatever questions or subjects for discussion this book may open, its importance at this time cannot be denied, and the full appreciation of its merits by the steam-fitting public is given by the fact that in less than three months it has run out the first edition. R. B.

A New System of Ventilation. By Henry A. Gouge. New York: D. Van Norstrand, 1881. Fourth edition, enlarged with new illustrations.

The title-page declares this book to be "A Book of the Household" and bears the following quotation as a motto: "If we breathe a gas that is noxious, or air that contains a very small proportion of carbonic

acid, we die."—Anatomy, Physiology and Hygiene, by Professor John C. Draper.

The preface sets out "Theories of Ventilation have had their day * * * * Nothing is worthy to be called Ventilation that cannot *show by measure* the necessary number of cubic feet of air removed every minute the year around."

With such a commencement it may be supposed that the "new system" will establish definitely what is to be done and how to do it.

An innocent reader might question Prof. Draper's remark, and while admitting that all who breathe air will die, desire to know or to be told how small a quantity of carbonic acid will kill them. Mr. Samuel Weller's account of the clerk in a government office who tried the three shillings worth of crumpets, toasted 'em all, ate 'em all, and then blew his brains out, on principle, could be paralleled. People do die from suicide after visiting crowded beer gardens repeatedly. Perhaps the proportions of CO^2 imbibed and inhaled are *too large* to kill.

But what does the author himself give out to be the proper quantity of air for each person, for light, etc. "which a room is expected to contain" "for every day in the year, in spite of wind and weather?" Alas! the entire 170 pages octavo do not have a word to say on these points. It is apparent "theories have had their day" and only "the system" of supplying an unknown quantity remains. What a development of novel algebra this proposition discloses?

It is not fair to quote a few words of each work, and from the text to convey an unfair deduction, so there is now given a larger quotation from page 106 "What is, and What is not, Ventilation."

"Characteristics of Gouge's System.

"Our distinctive proposal is not simply to put up certain ventilating apparatus, nor to introduce such flues, etc., as according to the philosophy of heat and gases ought, theoretically, to create the desired movement of air; nor merely to remove, in a general way, such impurity or slowness of air as may be noticed by the senses. All such things as these are matters of opinion and doubt, and the most favorable estimation of them can be but indefinite. On the contrary, the definite, tangible thing we in all cases contract to do, and about which there can be no mistake or dispute is to exhaust (and replace) any prescribed volume of air per minute, whether 50 or 5000 cubic feet, at the outlet of each room, replacing the same continually with a like quantity of fresh air,

warm or cool to suit the season; and delivering the result by measure as that of the yard stick or bushel. This, and this alone, is what WE mean by Ventilation."

It would appear from the above that the Science of Ventilation (dropping the word theory) must hereafter rest on no authority or computation but on Mr. Gouge's guess. Far be it from the writer of the present notice to say that this guess may not be better than some people's hypotheses (not to say theory).

The next information to be derived from "a book for the household" is how to effect the ventilation thus "definitely established." This is set forth as follows "What then is our motive power?" "It is furnished by an ordinary argand gas burner, operating through a peculiar form of flue so constructed as to near the well known velocity of flames, or on inductive power, entraining [*sic*] through precisely adjusted orifices, copious current of air; such as we perceived when a flame is started with paper, straw, or shavings at the draft throat of any well-constructed chimney or stove." It is to be supposed that the word entraining is derived from the French "*entrainèr*," to draw along, as the proposition for formation of an air injector with the ascension of the heated current of a gas jet for central induction column implies the *drawing along* of other currents to some limited extent.

Now it is not to be gainsaid that this method (as old as the beginning of this century at least) will effectively induce an efflux from a source provided systematically, or surreptitiously, with a corresponding influx; but it cannot be admitted to be an economical method of producing the movement of any large quantity of air. Such as, for instance, would seem to be necessary or desired from a crowded hall for a long session. And the "system" would be found difficult to regulate if thirty or forty such *induction flues* took out of the same room or even if more than one flue thus discharged.

For the merits or demerits of this "system" in method this book notice does not seem called upon to discuss very fully. The merits are set forth completely by numerous testimonials of high respectability with a large number of references from which it seems impossible not to draw the inference that the author's practice is based on further data than he communicates to the general public, and that his success ought to secure him an extensive business in his profession.

R. B.

Franklin Institute.

HALL OF THE INSTITUTE, March 15, 1882.

The meeting was called to order at the usual hour, with Vice President J. E. Mitchell in the chair.

There were present 154 members and 28 visitors.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers and reported that at the last meeting of the Board 17 persons had been elected members of the Institute, also that, on the application of the following members, they had been authorized to constitute the Electrical Section of the Franklin Institute, viz.:

Robert E. Rogers, M.D.,	N. H. Edgerton,
Alex. E. Outerbridge, Jr.,	W. W. Griscom,
Wm. D. Sargent,	Horace W. Sellers,
Addison B. Burk,	Wm. P. Tatham,
David Brooks,	D. S. Holman,
Edwin J. Houston,	Wm. H. Wahl,

John J. Weaver.

Mr. W. Barnet LeVan then read the first paper of the evening on the subject of Rapid Transit—Past, Present and Future. The speaker described the gradual development of the methods of transit and offered some ingenious suggestions as to the possibilities of the future. He illustrated his remarks with the use of a number of lantern pictures. Remarks were made upon the paper by Messrs. Orr, Mitchell, Burk, Nystrom and Cooper.

Mr. W. U. Greene followed with a paper on the Mears Chlorination Process, a modification of Plattner's process of treating auriferous ores, the special peculiarity of which resides in the use of chlorine under pressure. The paper was discussed by Prof. Koenig and Mr. Grimshaw, and has been referred to the Committee on Publication for insertion in the JOURNAL.

At the request of the Secretary, Prof. Koenig made some remarks upon the Davis Process of Precipitating Gold by Carbon, describing his own experiments made with the view of ascertaining whether the action of the carbon was a chemical or physical one, or both. An abstract of Prof. Koenig's remarks has been referred to the Committee on Publication. Prof. Houston remarked that he had just been making a series of investigations into this subject and confirmed certain statements of the former speaker.

Mr. Chas. A. Moore, of New York City, next made some remarks upon the Nickel-seated Pop Safety Valve, invented by Mr. Geo. W. Richardson, and illustrated the subject with the aid of the lantern and by sectional specimens of the valves themselves.

Owing to the lateness of the hour, the President announced that the description of "An Improved Feed-water Heater," which was to have been made by Mr. Geo. S. Strong, had been postponed, by request, until the April meeting.

The Secretary, after referring to some interesting correspondence respecting the Panama Canal and the Hudson River Tunnel, confined his report to the description of a few mechanical novelties, a number being reserved for the next following meeting.

The Electro-Massage instrument of Dr. John Butler was shown and described. It combines in one apparatus the operations of kneading or manipulation of the muscles and joints with the application of electricity. It was sent for exhibitian by the Dynamo-Electric Manufacturing Co., New York.

An ingeniously constructed opera-glass was shown, with eye-pieces hinged to the frame of the apparatus in such a manner that when closed the opera-glass forms a single tube, making it much more convenient to carry, and when required for use can be readily opened in the form of the well-known double tube instrument. These glasses were sent for exhibition by Mr. W. M. McAllister, of Philadelphia.

A novel plan of insulating electric light wires by means of a series of porcelain buttons, making a flexible and indestructible insulating covering for the wires was also shown. The buttons are made of sizes to correspond to the size of wire or wires to be covered and are pierced with as many openings as there are wires to be strung upon one line. This mode of button insulation is intended for heavy as well as for light wires. Where the wires run in-doors, no further protection than the porcelain buttons is considered necessary; where the line is carried underground, it is recommended to carry in a metallic pipe and to fill the vacant space by forcing in some plastic composition like asphaltum. This insulation was sent for exhibition by Mr. P. B. Delaney, of New York.

A Motion Indicator, Regulator and Alarm was shown, designed for the use of flour and grist mills and all machinery where a certain and uniform motion is necessary in order to obtain good results. The apparatus operates by centrifugal force. A pair of governor balls,

when the speed is what it should be, rotate without alarm, but when the speed is either above or below that for which it is set, the balls strike a projecting arm or pin which communicates with a gong and rings a continual alarm. The number of revolutions is indicated on a dial. The apparatus was sent for description by N. P. Bowsher, South Bend, Indiana.

A number of samples of Rubber-covered Carriage Steps, for carriages of various styles, were shown. In these the rubber gives a soft, elastic treading surface, which being ornamented with ribs, etc., affords a secure foothold. These specimens were sent for inspection by the Rubber Step Manufacturing Company, Boston.

A specimen of an Anti-friction Bearing for shafting, carriages, team wagons, cars, etc., was described. The bearing surfaces were made of a series of hardened steel rollers. The inventor claimed by the use of this bearing to be able to dispense with lubricants and to save considerable power. This exhibit was made in behalf of John G. Avery, Spencer, Worcester co., Mass.

Mr. Robert Grimshaw, Secretary of the Mechanical Section, announced, under the head of new business, that the next meeting of the section would be held on Monday evening, March 20th, at which time there would be presented for discussion and action the very important subject of determining and recommending a national standard gear-tooth system, by which all gears of the same pitch, no matter what the pitch circle, should gear properly and truly together.

Mr. D. S. Holman made the announcement of a lecture to be delivered before the Phonetic Short-hand Section on Wednesday, March 22d, upon which the meeting was adjourned.

WILLIAM H. WAHL, *Secretary.*

LIST OF BOOKS ADDED TO THE LIBRARY DURING JANUARY, FEBRUARY AND MARCH, 1882.

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American Stationer. Vol. 7. N. Y.
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Annual Reports of Births, Marriages and Deaths in Michigan for 1874 and 1875. Presented by Superintendent of Vital Statistics.

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Armengaud's Publication Industrielle. Vols. 11—27. Paris.

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Specifications and Drawings. Vols. 21—41. London, 1880.
Subject Matter Index. London, 1881.

Building Construction. Notes on. Vol. 3. London, 1879.

Bureau of Education. Circulars of Information. Nos. 4 and 5. Washington, 1881. Presented by the Bureau.

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Colonial History of the State of New Jersey. Documents relating to. Vol. 2, 1687—1703. Newark, 1881.
Presented by the State Librarian.

Commerce and Navigation, U. S. Report of the Chief of Bureau of Statistics for 1880. Presented by the Chief of Bureau.

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Presented by the Department of State.

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Germanischer Lloyd. Internationales Register. Berlin, 1882.
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Gillmore, Q. A. Report on Strength of Building Material. Washington, 1874. Presented by Engineer Department.

Gouge, H. A. Ventilation. New York, 1881.

Harvard College Observatory, Thirty-sixth Report of Director of. Cambridge, 1882. Presented by the College.

Ingersoll, E., and H. W. Elliott. Fisheries Industries. Washington, 1881. Presented by Census Bureau.

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Journal de l'Union des Eaux des deux Mers. June—December, 1856. Presented by Prof. J. E. Nourse.

Lewis, Jr., L. Bank of North America, History of. Philadelphia, 1882.

Lobintz, M. Lecture. Paris, 1868. Presented by Prof. J. E. Nourse.

Lunge. Sulphuric Acid. Vol. 3. London, 1880.

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Mallory Steering and Propelling Screw, Report on. Washington, 1882. Presented by Engineer Department.

Marine and Fisheries Department, Canada.
Annual Reports of the Department for 1879 and 1880.
Fisheries Statements for 1877 to 1880.
List of Lights and Fog Signals, 1879 and 1880.
List of Vessels on Registry Book in 1877.
Reports of Board of Steamboat Inspection, etc., for 1879 and 1880. Presented by the Department.

Message of the President of the United States to Congress. Washington, 1880. Presented by Department of State.

Meteorological Office, Quarterly Weather Report of. January—March, 1876. London. Presented by the Office.

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Nichols, W. R. Publications of Massachusetts Institute of Technology. Cambridge, 1882. Presented by the Author.